RECEIVED
APR 21 53
LIBRARY

THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

JANUARY-FEBRUARY, 1953

Nickel Page

Nickel: Occurrence, Properties, Uses 2
Compounds of Quadrivalent Nickel 2
Metal Carbonyls: Preparation and Properties 2
Synthetic Shandite and Analogous Compounds 3
Magnetization of Nickel as a Function of Temperature 3
Magnetostriction and the Δ-E Effect in Nickel 3
Electrical Resistivity of Nickel as a Function of Drawing Temperature 3
Thermogalvanic Potential of Nickel in Neutral Sulphate Solutions 4
Raney Nickel Catalyst 4
Monoximes as Reagents for Nickel and Other Metals 4
Determination of Nickel in Cracking Catalysts 4
Polarographic Determination of Nickel in Aluminium Alloys 5
Determination of Traces of Nickel in Oils 5
Occurrence of Metals in Petroleum Distillates 5
Spectrochemical Determination of Magnesium in Nickel 5
Reaction between Wool and Nickel-Ammonium Hydroxide 6
" " Proteins and Nickel-Ammonium Hydroxide 6

Electrodeposition and Other Coating Methods

Effects of Iron in Nickel-Plating Solutions 6
Alternatives to Nickel Plating: Industrial Experience 7
Corrosion Tests on Tin-Nickel Alloy and Nickel/Chromium Coatings 7
Increasing Throwing Power of Nickel-Plating Baths by Use of Sulphites 8
Properties of Electrodeposited Nickel: A.E.S. Report: Corrected Data 8
Cast Nickel Anodes 8
Coatings for Use in Various Types of Atmosphere: D.I.N. Schedules 8
Nickel Plating of Plastics 9
Nickel Plating of Stainless Steel Prior to Brazing 9
Rapid Analysis of Nickel-Plating Solutions 9

Non-Ferrous Alloys

Optical Characteristics as Related to Crystal Orientation in Monel 9
Temper-Hardening of Copper-Manganese-Nickel Alloys 9
Electrolytic Manganese: Use in Nickel-containing Alloys and Steels 10
Order-Disorder and Related Phenomena in Nickel-Chromium Alloys 10
Nickel-Lanthanum Alloys: Magnetic Properties 11
Nickel-Zinc Alloys 11
Zirconium-Nickel Alloys 11

Nickel-Iron Alloys

Magnetic Powders: Production, Properties, Uses 11
Behaviour of Nickel-Iron Alloys under Current Pulse Conditions 12

Cast Iron Page

Mechanical Properties of S.G. Iron 12
S.G. Iron Gears 13
Ductile Iron in Water Works Equipment 13
Ni-Resist (High-Alloy) Corrosion-Resisting Cast Iron 13
Ni-Resist Valves in Contact with Hydrochloric Acid Vapours 13
Ni-Hard Liners in Rod Mill 13
Ni-Hard Guides for Winding Winches. 14

Constructional Steels

Formation of Bainite in Nickel-Alloy and Other Steels 14
Temper-Brittleness in Low-Alloy Steel Weld Metal 14
Sub-Zero Notch Toughness of Nickel-Alloy Steels 15
Transition from Ductility to Brittleness in Pressure-Vessel Steels 15
Use of Nickel-Manganese-Molybdenum-Silicon High-Tensile Steel in Aircraft 16
Welding of Nickel-containing Steels 16
U.S. Government Specifications for Alloy Steels 16
Analysis of Iron and Steel: Determination of Vanadium 16

Heat- and Corrosion-Resisting Alloys

Limiting Creep and Stress-Rupture Values for Nickel-containing Materials 17
Rotating Discs for Aircraft Gas-Turbine Rotors 17
Influence of Flaking-off of Scale in Accelerated Life Testing of Wires 17
Heat-Resisting Casting Alloys used in U.S.A. 17
New High-Temperature Alloy: N.A. 22H 17
Nickel-Chromium-Iron Alloys in Boiler Furnaces and Superheaters 18
High-Temperature Mechanical Properties of Intermetallic Compounds 18
Timken 16-25-6: Production and Properties 18
Elevated-Temperature Embrittlement in Austenitic Chromium-Nickel Steels 19
Oxidation Characteristics of Nickel- and Cobalt-base Alloys at High Temperatures 20
Extrusion of High-Alloy Materials by the Ugine-Séjournet Process 21
Resistance of Nickel-containing Alloys to Salt-Bath Media 21
Corrosive Attack as a Factor in Design and Lubrication 22
Influence of Operating Conditions on Resistance to Corrosion 22
Corrosion by Water: Effects of Velocity 23
Corrosion Charts: Comments on Mode of Presentation 23
Corrosion Inhibitors: Reference List 23
Influence of Carbon Content on Acid-Resistance of Austenitic Nickel-Chromium Steels 23
Influence of Rate of Drawing on the Magnetic Properties of Austenitic Steel Wire 24
Stainless Steel for Non-Magnetic Applications 25
Precipitation-Hardening Nickel-Chromium Steels in Aircraft Construction 26
Stainless Steels used in Sweden 26
Welding and Flame Cutting of Stainless Steels 26
Gas Cutting of Stainless Steel 27
Cupro-Nickel Alloys containing Iron 27
Copper-Nickel-Silicon Alloy Resistant to Stress-Corrosion 27
X-Ray Fluorescent Analysis of High-Alloy Steels 28

Patents 28

3235-33-2

VOLUME 26 NUMBER 1-2

THE MOND NICKEL COMPANY LTD • SUNDERLAND HOUSE, CURZON STREET, LONDON, W.1
Telephone:- Grosvenor 4131

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

NICKEL

Nickel: Occurrence, Properties, Uses

U.S. DEPT. OF THE INTERIOR, BUREAU OF MINES: '1950 Materials Survey: Nickel.'
Compiled (with co-operation of U.S. Geological Survey) for National Security Resources Board. *Published by U.S. Govt. Printing Office*, 1952.
Price 2 dollars.

This report, which is one of a series of basic surveys on various strategic and critical materials, has been compiled by a staff specially assembled for the purpose, and reviewed by specialists in various U.S. Government Departments closely concerned with the subject.

Chapter I opens with a brief note of the position of nickel relative to other ferro-alloy metals, followed by a general outline of the nickel industry and a summary account of world production and resources, and conditions of emergency supply and demand.

Chapter II deals in detail with production up to 1900 and from 1901-1925, and reviews the development and activities of the various major companies in the Canadian area. Some operating results obtained by Inco and by Falconbridge over various periods up to 1950 are also recorded, and a table shows prices of nickel from 1830 to 1950. The nickel output of other countries is also considered. The chapter closes with a condensed account of major features of processes used by various companies for extraction of nickel.

Chapter III covers forms of nickel, its properties, and uses, and also the composition, properties and uses of ferrous and non-ferrous alloys of which nickel is an integral constituent. Much of the tabular and graphical data presented is taken from National Bureau of Standards Circular 485, 'Nickel and its Alloys'.

Chapter IV is concerned with nickel-bearing minerals, and the nature and location of the three main classes of ore in which nickel is found.

Chapter V contains a review of the nickel reserves of the world, classified according to the countries of origin and the nature of the ores.

Chapter VI deals with the economics of extraction, in relation to the nickel contents of the respective types of ore and the processes involved in treating them.

Chapter VII covers processing, from the technical standpoint. An account is given of (*a*) mining methods, as used in Sudbury, and as employed for lateritic ores; (*b*) milling practice; and (*c*) metallurgy, comprising a description of the main features of methods used by International Nickel Company, Mond Nickel Company, Société le Nickel, Falconbridge, Nicaro Nickel Company, and others, for extraction of nickel from the treated ores and concentrates.

Chapter VIII describes materials marketed, and methods of selling used by International Nickel Company and its associates, and by Falconbridge. Some details are given of relevant U.S. tariffs.

Chapters IX to XII provide various forms of data on supply and demand, for previous periods and as obtaining at the time of compilation of the report. Information given includes figures for world production 1926-1950 and the position of the U.S.A. during that period; U.S. imports (by country of origin and by classes); U.S. and Canadian exports; stocks of nickel held in U.S.A. over various recent periods; consumption by forms and/or uses in U.S.A., U.K., and other countries.

Chapter XIII deals with conservation of nickel during emergency periods. The discussion covers conservation and substitution in low-alloy steels, stainless steels, non-ferrous alloys, electroplating, and permanent-magnet alloys, also use of boron-treated steels.

Chapters XIV to XVI include an account of existing and planned facilities for nickel production, U.S. Government controls during emergency periods, and a classified *bibliography*, relating to occurrence, production, properties and uses of nickel-containing materials.

Compounds of Quadrivalent Nickel

W. HIEBER and R. BRÜCK: 'Complex Compounds of Quadrivalent Nickel.' *Zeitsch. für anorganische Chemie*, 1952, vol. 249, Aug., pp. 13-27.

Starting from Ni(II) compounds of organic thio-acids of complex structure, 6-fold co-ordinated anionic complexes may be derived by adding OH- or S_2-ions. In these the nickel parts relatively easily with two further valency electrons, to transform to a krypton-type configuration. Full details are given of mode of preparation of various organic complexes of quadrivalent nickel.

see also—

Metal Carbonyls: Preparation and Properties

W. HIEBER and R. BRÜCK: 'Metal Carbonyls. Paper No. 50. Significance of Quadrivalent Nickel Complexes in Connexion with the Formation of Nickel Carbonyl.' *ibid.*, pp. 28-39.

This paper is one of a series of reports issued, by the senior author and his colleagues, at intervals over the past 25 years, on laboratory investigations of the conditions requisite for the formation of metal carbonyls, and the characteristics of the compounds formed.

In this paper it is pointed out that although nickel carbonyl is frequently formed in liquid-phase systems as a result of the interaction of nickel compounds of organic thio-acids with carbon monoxide, the reason for, and mechanism of, the reaction have never been explained. It is now reported that compounds of

quadrivalent nickel are the determining factor: stable quadrivalent nickel compounds are formed, resulting in a 50 per cent. yield of nickel carbonyl. In systems in which compounds of quadrivalent nickel unstable towards carbon monoxide would be expected, quantitative formation of carbonyl is made possible by the valency-change chain Ni(II)→Ni(IV)→Ni(II), which acts catalytically. The carbon-monoxide reaction does not take place without the pre-existence of conditions essential for formation of a quadrivalent nickel compound. These discoveries have made possible the development of a laboratory method for preparation of nickel carbonyl at ordinary pressures. Ni (II) phenyldithiocarbaminate is used as the starting material. This is dissolved in water, in presence of sodium sulphide, and carbon monoxide is passed through the solution. Details of the method are given.

See also two further papers in the series referred to in the following abstracts.

W. HIEBER and E. O. FISCHER: 'Metal Carbonyls. Paper No. 52. The Mechanism of the Carbon Monoxide Reaction of Nickel (II) and Cobalt (II) Salts in Presence of Dithionite.' *ibid.*, Sept., pp. 292-307.

A detailed report is made of experiments on (quantitative) formation of nickel and cobalt carbonyls by reaction of their salts in ammoniacal solution with carbon monoxide, in presence of sodium dithionite. The reaction is based on oxidation of dithionite to sulphite.

W. HIEBER, E. O. FISCHER and E. BOCKLEY: 'Metal Carbonyls. Paper No. 53. New Laboratory Methods for the Production of Nickel and Cobalt Carbonyls.' *ibid.*, pp. 308-16.

By application of the discoveries described in the previous paper, new and improved methods for formation of the carbonyls of nickel and cobalt have been developed. Procedure for formation of pure $Ni(CO)_4$ is fully described.

Synthetic Shandite ($Ni_3Pb_2S_2$) and Analogous Compounds

J. E. HILLER: 'Synthetic Shandite, $Ni_3Pb_2S_2$, and Analogous Compounds with Selenium and Tellurium.' *Neues Jahrbuch Mineralogie, Monatshefte*, 1951, pp. 265-77; *Chemical Abstracts*, 1952, vol. 46, July 25, p. 6552.

Reports preparation and examination of shandite and a complete series of solid solutions with $Ni_3Pb_2S_2$. Additions of tellurium to either the sulphide or the selenide gave inhomogeneous mixtures.

Magnetization of Nickel as a Function of Temperature

R. S. TEBBLE, J. E. WOOD and J. J. FLORENTIN: 'The Temperature Variation of the Magnetization of Nickel in Low and Moderate Fields.' *Proc. Physical Soc.*, Sect. B, 1952, vol. 65, Nov. 1, pp. 858-71.

An account is given of measurements on the reversible changes in magnetization accompanying change in temperature in annealed nickel, and the results are discussed in relation to the work of BATES and others on the temperature changes produced by adiabatic changes in magnetization (the magneto-caloric effect). It is found that at relatively high fields, where the magneto-caloric effect is mainly reversible, the results are in good agreement with those obtained from direct magneto-caloric measurements: for low field values a quantitative separation of the reversible and irreversible components of the magneto-caloric effect has been carried out. The result of an analysis of the reversible heating effect is compared with the estimate given in the theoretical investigation of STONER and RHODES, and it is suggested that, over the low-field range considered, rotational processes predominate. The composition of the nickel used in the experiments is given as nickel 99·71, iron 0·06, manganese 0·01, silicon 0·06, carbon 0·02, magnesium 0·13, sulphur 0·008, per cent.

Magnetostriction and the Δ-E Effect in Nickel

H. NÖDTVEDT: 'Magnetostrictive Effect and the Δ-E Effect in Nickel.' *Nature*, 1952, vol. 170, Nov. 22, pp. 884-5.

In connexion with a note on sound propagation in ferromagnetic materials (*ibid.*, 1951, vol. 168, Dec. 1, p. 963) the writer reports experiments showing that magnetostrictive effects may modify changes in resonant frequencies caused by the Δ-E effect.

Change of Electrical Resistivity of Nickel as a Function of Drawing Temperature

T. BROOM: 'The Effect of Temperature of Deformation on the Electrical Resistivity of Cold-Worked Metals and Alloys.' *Proc. Physical Soc.*, Sect. B, 1952, vol. 65, Nov. 1, pp. 871-81.

Increase in electrical resistivity occurring on cold working of cubic metals and alloys indicates that the deformation generates lattice disturbances which can shatter conduction electrons. The work described in this paper was undertaken to acquire further knowledge of these disturbances, by study of changes in resistivity. Special apparatus was devised for drawing wires at temperatures between −183°C. and +100°C., and with it investigations were made of the behaviour of the following materials, selected as representative of those showing increase of resistivity of the order of 2% when deformed at room temperature: aluminium, copper, nickel, iron and 50-50 silver-gold alloys. An α brass was also studied, as being a material which gives relatively high increase of resistivity on deformation at room temperature, and the ordered alloy Ag_3Mg was included in order to observe the effect of temperature of deformation on increase in electrical resistivity of super-lattices. A full description is given of apparatus and technique, and the significance of major sources of error is discussed.

Effects of temperature and degree of deformation, on the resistivity of the respective materials, are shown in a series of curves, and the values at the four temperatures considered are tabulated. The results show that for the materials studied increase in electrical resistivity due to cold work depends markedly on the temperature of deformation. At any one temperature

the increase with strain is at first rapid and then becomes more gradual. The effect of decrease in temperature of deformation is to increase the rate of change of resistivity at all strains, and to prolong the initial period of rapid increase. It was found that the change of resistivity with deformation was dependent on relation of temperature of deformation to that of recrystallization. The results explain quantitatively the apparently anomalous resistivity increases previously reported for tungsten and molybdenum. It is suggested that a unified theory of the effect of deformation on the resistivity of both metals and alloys can be based on stacking faults.

An appendix to the paper contains a summary of data obtained by other investigators relative to changes in resistivity of metals and alloys on deformation at room temperature. This table includes values for nickel, Ni_3Fe and Ni_3Mn.

Thermogalvanic Potential of Nickel in Neutral Sulphate Solutions

D. S. CARR and C. F. BONILLA: 'Thermogalvanic Potentials. II. Nickel in Neutral Sulfate Solutions.' *Jnl. Electrochemical Soc.*, 1952, vol. 99, Dec., pp. 475-82.

Among the causes of corrosion is the effect of differential heating, designated thermogalvanic corrosion. This is a form of galvanic action in which different areas of a metal develop different solution potentials, causing metal to dissolve from one surface and deposit on another as a result of the temperature difference.

The mechanism of a thermogalvanic cell is comparable to that of a metallic differential thermocouple, the intermediate metallic element being replaced by an electrolytically conducting solution. At the electrodes the passage of current is accompanied by a Peltier type of heat effect, as well as by transfer of electrode material, while in the temperature gradients the passage of current is accompanied by Thomson heat effects. Metallic conduction across the junction is replaced by electrode reactions which are the reverse of each other, the oxidizing agent which is reduced at the cathode being regenerated at the anode. Thermogalvanic corrosion can proceed indefinitely if not prevented by such factors as the formation of insoluble films.

A summary of earlier thermocell investigations is given as an introduction to the present paper, and a second table contains a digest of the deposition, normal, and standard electrode potentials of nickel published since the classic summary prepared by WILSMORE in 1900 (*Zeitsch. physik. Chem.*, vol. 35, p. 316). The authors report measurements of the thermogalvanic potential developed by carefully purified nickel powder in several concentrations of neutral nickel sulphate solution, under temperature differentials up to 100°C. Apparatus specially devised for this research is described and illustrated.

Reproducible values of the thermodynamic potential were obtained, and were found to vary more or less linearly with difference in temperature, and exponentially with nickel concentration. The hotter nickel surface was always negative with respect to the colder surface, thus having a tendency to corrode anodically. Under average conditions the thermogalvanic potential developed was about 0·89 millivolt per °C.

The standard potential of the nickel electrode was computed from isothermal measurements against a calomel electrode, and found to be approximately −0·232 volt. on the normal hydrogen scale.

Raney Nickel Catalyst

C. VANDAEL: 'Raney Nickel.' *Industrie Chimique Belge*, 1952, vol. 17, pp. 581-5: *Chemical Abstracts*, 1952, vol. 46, Oct. 25, p. 9396.

Report of investigation to determine whether the activity of Raney nickel catalyst is due to its finely divided state or to formation of a hydride. The observations made (for which see *Chemical Abstracts*, *loc. cit.*) indicate that the catalytic effect of the material is attributable to the reducing activity of the hydride NiH_2.

Monoximes as Reagents for Nickel and Other Metals

R. PALLAUD: 'Various Monoximes (as Organic Reagents for Metals).' *Chimie Analytique*, 1952, vol. 34, No. 2, pp. 39-42.

Review of the properties and applications of the following monoximes, for use in the determination of the elements shown in brackets after the respective compounds:—

Formaldoxime (copper,i ron, manganese, nickel).
Acetaldoxime (cobalt, copper, nickel).
Acetoxime (cobalt).
Aminoacetoxime (copper, iron).
Diaminoacetoxime (copper, cobalt, iron).
Oxime of acetodicarboxylic acid (silver, cobalt, copper, iron, mercury, lead).
α-benzaldoxime (copper, nickel).
Isobutyraloxime (cobalt, copper, nickel).
Monoxime of phenylglyoxylic acid (cobalt, copper, nickel).
Piperonaloxime (copper).
Cinnamylidene anisylidene acetone oxime and dianisylidene acetone oxime (tungsten).
β-furfuraldoxime (palladium).
Benzamidoxime (copper, nickel).
β-toluamidoxime (copper, nickel).

Determination of Nickel in Cracking Catalysts

C. W. KEY and G. D. HOGGAN: 'Spectrographic Method for Analysis of Cracking Catalysts.' *Analytical Chemistry*, 1952, vol. 24, Dec., pp. 1921-5.

In the processing of petroleum hydrocarbons with cracking catalysts it is necessary periodically to analyze the catalyst, with particular reference to foreign materials which may be introduced during manufacture or in subsequent contact with the petroleum feed stocks or processing equipment. In some cases contact with these contaminants may considerably reduce the activity of the catalyst, thus causing substantial economic losses. Particular interest is centred on the presence of nickel, vanadium, sodium, iron, and chromium, in processes in which a silica-alumina cracking catalyst is used.

Various chemical methods of analysis have been used in this connexion, but they are time-consuming,

and in many cases are not sufficiently sensitive to yield accurate results in estimating the low concentrations normally encountered.

In the spectrographic method described in the present paper a rotating disc electrode is composed of powdered catalyst, lithium carbonate, graphite and cobalt. It was found to provide excellent sampling areas. A high-voltage spark discharge gave good reproducibility and sensitivity. Application of the method has cut down time required for analysis, and given a higher degree of accuracy, as compared with results obtained by conventional chemical analysis. Increased production, at lower operating cost, combined with improved quality in the product, has resulted from the more accurate and more frequent analyses which are thus possible. Complete details of procedure are given, with typical analytical data.

Polarographic Determination of Nickel in Aluminium Alloys

E. C. MILLS and S. E. HERMON: 'The Polarographic Determination of Nickel in Aluminium Alloys.' *Metallurgia*, 1952, vol. 46, Nov., pp. 259-62, 266.

The paper reports investigations in the laboratories of High Duty Alloys, Ltd., made to develop a method which would cover determination of nickel in most types of aluminium alloy, including special and experimental types containing combinations of normal and less common elements. It was especially desirable that the method should be applicable to a nickel range of 0·02 to 0·5 per cent. in normal alloys.

A full account is given of the investigation of the nickel wave form obtained under various conditions of operation, of the effect of interfering elements, and of conditions requisite for analysis of individual alloys. In the method finally developed the procedure is as follows: After initial solution of the sample, and removal of the copper and silicon (if necessary), the nickel is separated from the aluminium by sodium-hydroxide precipitation, and subsequently converted to nickel chloride. A polarogram of the nickel is then recorded in pyridine/pyridinium chloride-base electrolyte, using gelatin as maximum suppressor. Some typical results obtained by this method are compared with standard values.

Determination of Traces of Nickel in Oils

O. I. MILNER, J. R. GLASS, J. P. KIRCHNER and A. N. YURICH: 'Determination of Trace Metals in Crudes and Other Petroleum Oils: Analysis for Iron, Nickel, Vanadium, and Copper.' *Analytical Chemistry*, 1952, vol. 24, Nov., pp. 1728-32.

In view of the discovery that iron, nickel, vanadium and copper, when deposited on a cracking catalyst, will markedly reduce its activity, the petroleum industry is increasingly interested in traces of these elements. The vanadium pentoxide problem associated with high-temperature conditions in gas turbines has accentuated the need for a more accurate knowledge of the presence of vanadium in fuel oils. In this connexion it has been necessary to develop quantitative analytical methods for estimation of traces of the elements, not only in crudes and residues containing relatively high concentrations, but also in distillates and cracking stocks, in which the metal content is of the order of less than 0·1 p.p.m.

The method described by the present authors comprises a novel wet-ashing technique, by which crudes and petroleum fractions can be conveniently reduced to an inorganic residue with minimum risk of loss of metal. The ash is solubilized, and separate aliquots are taken for determination of the individual elements. Iron, nickel, and vanadium are determined photometrically, after reaction with *o*-phenanthroline, dimethylglyoxime, and phosphotungstic acid, respectively. Copper is estimated polarographically, after preliminary isolation by micro-electrodeposition. Data are presented to establish the accuracy of the recommended method, when applied to metal concentrations as low as 0·1 p.p.m. It has been applied to typical petroleum stocks, and its effectiveness in determining material balances in refining processes is demonstrated. The values found for the iron, nickel, vanadium, and copper content of various crude oils are also included.

See also—

J. H. KARCHMER and E. L. GUNN: 'Determination of Trace Metals in Petroleum Fractions.' *ibid.*, pp. 1733-41.

This paper describes procedure in which, by rigid control of sampling and of variables in combustion and ignition, a reproducibility of about ±10 per cent. in the ash range of 0·0001 to 0·01 per cent. and ±5 per cent. in the range of 0·01 to 0·3 per cent. is obtained. Colorimetric and spectroscopic methods described have proved capable of determining individual metals in milligram quantities of ash substance, the relative precision of these methods being ±10-20 per cent. Spectroscopic methods providing an accuracy of ±20 per cent. may be applied to the direct determination of trace metals in certain stocks, to overcome some of the problems associated with indirect chemical methods.

Occurrence of Metals in Petroleum Distillates

R. A. WOODLE and W. B. CHANDLER: 'Mechanism of Occurrence of Metals in Petroleum Distillates.' *Industrial and Engineering Chemistry*, 1952, vol. 44, Nov., pp. 2591-6.

Report of study of the mechanism by which vanadium, nickel and other metals contained in the parent crude oil enter petroleum distillates. The data obtained support the conclusion that the presence of metals in vacuum distillates is caused by actual volatilization of metal compounds indigenous to the crude oil.

Spectrochemical Determination of Magnesium in Nickel

W. NIELSCH: 'Spectrochemical Determination of Magnesium in Nickel.' *Zeitsch. für Metallkunde*, 1952, vol. 43, Oct., pp. 370-2.

Chemical methods for estimation of magnesium in nickel present certain difficulties, particularly when

small samples are involved. This paper describes spectrochemical procedure by which magnesium over the range 0·001 to 1·0 per cent. can be accurately determined in nickel or solutions of nickel salts. The author discusses, *inter alia*, preparation of magnesium-free nickel-salt solutions for use in establishing the calibration curve; the influence of variation in experimental conditions, on accuracy obtained; the interpretation of the experimental results.

Reaction between Wool and Nickel-Ammonium Hydroxide

J. W. BELL and C. S. WHEWELL: 'The Reaction between Wool and Nickel-Ammonium Hydroxide. I. The Adsorption of Nickel by Wool from Solutions of Nickel-Ammonium Hydroxide.'
Jnl. Soc. Dyers and Colourists, 1952, vol. 68, pp. 299-305.

It was found that the amount of nickel adsorbed and the rate of the reaction were affected by the concentration of the reagent, by time, and by temperature. Maximum nickel adsorbed was 22 per cent. For further details see *Chemical Abstracts*, 1952, vol. 46, p. 9853.

Reactions Between Nickel-Ammonium Hydroxide and Proteins

J. W. BELL and C. S. WHEWELL: 'A Note on the Action of Nickel-Ammonium Hydroxide on Proteins in General.' *ibid.*, p. 305.

During the experiments described in the preceding paper it was noticed that when samples of wool were immersed for long periods in moderately concentrated nickel-ammonium hydroxide solution (5-10 g. of nickel per litre) the wool became exceedingly degraded, and a red coloration appeared in the bottom of the reaction vessel. Since adsorption of nickel by wool is accompanied by development of a reddish-brown colour, it was presumed that the red solution contained a complex of nickel and dissolved protein. In further experiments, in which wool and hair were treated at room temperature for long periods in nickel-ammonium hydroxide solutions of various strengths, it was found possible to dissolve large amounts of protein material, the remainder being converted to a gelatinous mass which could usually be lifted out of the solution. The clear, red liquor had a high tinctorial value. Further tests showed that nickel-ammonium hydroxide combines not only with wool, but also with feather keratin, hide powder, egg albumen, casein, and formalized casein. Some proteins, when dissolved, yield red solutions, from which metal-containing complexes may be obtained by addition of ethyl alcohol. The nickel content of these complexes is high. It was also observed that polyglycine, for which there are few solvents, is soluble in concentrated solutions of nickel-ammonium hydroxide.

Oxidation Characteristics of Nickel at High Temperatures

See abstract on p. 20.

ELECTRODEPOSITION AND OTHER COATING METHODS

Effects of Iron in Nickel-Plating Solutions

D. T. EWING, A. A. BROUWER and J. K. WERNER: 'Effect of Impurities and Purification of Electroplating Solutions. I. Nickel Solutions. 6. The Effects and Removal of Iron.' *Plating*, 1952, vol. 39, Dec., pp. 1343-9.

The paper is the sixth in a series of reports issued by the American Electroplaters' Society Research Project 5. Previous investigations on the influence of iron as an impurity had been reviewed in an earlier report (*ibid.*, 1949, vol. 36, pp. 58-61; *Nickel Bulletin*, 1949, vol. 22, No. 3, p. 39).

In the experiments recorded in the present paper the effects of iron were studied in four types of nickel-plating solution: Watts type at pH 2·2 and 5·2, a nickel-cobalt alloy type at pH 3·75, and an organic type at pH 3·2. Since earlier investigation had shown that iron in solution in such baths is predominantly in the divalent state, and that less than 10 per cent. of the total iron present is in the form of ferric ions, the iron was added as $FeSO_4.7H_2O$, to give the following iron concentrations: 2·5, 10, 25, 50, 100 and 200 p.p.m. Details of preparation of the deposits are given.

Six properties of the coatings were examined, as a function of the iron content of the solution from which they were deposited: appearance, adherence, ductility, hardness, salt-spray corrosion-resistance, and throwing power. Results, reported as per cent. changes from the properties exhibited by the deposits obtained from the corresponding standard solutions, are shown in graphs and tables. The general conclusions drawn are:—

'A whitening effect on the grey nickel deposits was observed with an iron concentration of 10-200 p.p.m. present in solution. The deposits from the bright nickel solution exhibited no change in appearance within the range of 0-200 p.p.m. of iron investigated.

'The nickel deposits from solutions containing 0-200 p.p.m. of iron evidenced no detectable change in the adherence of the deposits to the base metal.

'A slight initial decrease in the ductility of the deposits from the Watts-type solutions and the organic solution was found when the iron concentration reached 25-50 p.p.m. Increasing the concentration to 200 p.p.m. produced a further slight decrease in the ductility of the deposits. The nickel-cobalt deposits exhibited no detectable change in this property over the range of the impurity studied.

'In general, it may be stated that the deposits from each of the different types of solutions, with the exception of those from the alloy-type bath, showed little or no change in their salt-spray corrosion-resistance properties with from 0 to 200 p.p.m. of iron present in solution. The nickel-alloy deposits showed a 10-20 per cent. increase in corrosion-resistance with 25-200 p.p.m. of iron.

'The effect of iron on the throwing power of the four types of solutions containing up to 200 p.p.m. was insignificant.

'Nickel deposited from solutions containing 2·5-200 p.p.m. of iron generally exhibited an increase in hardness.

'In the case of the Watts pH 5·2 bath, the iron formed a noticeable precipitate in the solution. This, it is felt, caused some roughness, particularly on the horizontal section of the deposits from this solution.'

Study of removal of iron from nickel-plating solutions showed that this can be effected by high-pH treatment with nickel carbonate, to reduce it to a value of 25 p.p.m. or less, with no appreciable loss in nickel. By using an oxidizing agent a more complete removal of the iron is attained at a lower pH level, in a shorter time. A curve in the report shows the advantage of hydrogen-peroxide treatment as a method of removing iron at pH values above 5·0. The most economical and complete method for removal of iron is considered to be oxidation and high-pH precipitation. Iron may also be removed by high- and low-current-density electrolysis, but this method is ineffective if it is desired to lower the iron concentration below 50 p.p.m. without excessive deposition of nickel. Even at higher concentrations of iron electrolytic removal is a slow process.

Alternatives to Nickel Plating: Industrial Experience

'Substitute for Nickel Plate. A Survey of Industrial Experience.' Communication from the British Non-Ferrous Metals Research Association. *Electroplating*, 1952, vol. 5, Nov., pp. 361-6: see also editorial, p. 357.

Restriction in supplies of nickel for plating has raised many problems concerning the most effective use of the nickel available and the extent to which alternative coatings can be used. In face of recent developments in automatic plant, bright plating, etc., proposed alternatives to nickel+chromium plating must meet a number of requirements before they can be considered practicable. Their merits must be assessed not only in terms of the serviceability of the coatings, but also with reference to any new capital outlay involved, and the costs and technical performance of the plating process.

The British Non-Ferrous Metals Research Association is at present engaged on an extensive comparison of the various types of electrodeposited coating now commercially produced, and although full results are not yet available, a useful amount of information has been secured in response to a questionnaire circulated by the Association to companies interested in plated finishes. Firms who have supplied details of their experience in the use of 'substitute' finishes include several motor and accessory manufacturers, some concerned exclusively with contract plating, and companies in the light-electrical and domestic-appliance fields, who have internal plating departments. The replies received have been correlated in a series of tables (reproduced in this report), which summarize experience in the use of copper+chromium, tin bronze+chromium, tin-nickel, and other finishes.

The replies indicate that except for the copper+chromium type (with or without a thin nickel layer between the copper and the chromium), there is little production experience of alternative finishes, and that none stands out as equal at present to the standard nickel+chromium, either in reliability of the process under production conditions, or in performance of the product. The three most interesting alternatives are considered to be copper+chromium, tin-nickel, and tin bronze+chromium. The relative merits of these three are discussed.

The copper+chromium coatings can readily be applied without necessity for new plant, but as a process difficulties arise, due to poor coverage by the chromium, and to the need for more extensive polishing than is required in nickel+chromium plating. Also, the relative softness of the copper deposit is apt to lead to scratching of the thin chromium coating. Service experience indicates that a coating with as much as 0·002 in. copper and 0·0001 in. chromium on steel discolours after short exposure to industrial atmospheres. Use of thin nickel undercoats on copper confers a marked improvement. On steel a coating made up of 0·00015 in. nickel, 0·0005 in. copper, 0·00015 in. nickel+0·00002 in. chromium is said to be adequate for heavy duty in outdoor exposure. In such coatings no failures have been observed after 18 months. For indoor use, on steel, a coating of 0·001 in. copper, 0·00015 in. nickel, 0·00002 in. chromium has stood successfully for 7 months, and is considered to be equal to 0·0003 in. nickel. Particular attention is drawn, in this connexion, to the use of 0·0004 in. nickel+0·00002 in. chromium, followed by waxing, which is stated, in indoor exposure, to be the equal of normal nickel+chromium, though the comment is made that it is more difficult to maintain the thin nickel deposit fully bright, and that any polishing necessarily creates the hazard of polishing through. Although tin-bronze cannot be regarded as a satisfactory substitute for nickel, there is indication that it may, for some purposes, be superior to copper as an undercoat to nickel. Service testing of laboratory-produced tin-nickel coatings shows results which compare favourably with those obtained on nickel+chromium coatings, but pitting which is liable to occur in the alloy deposit will have to be eliminated in order to ensure satisfactory service life. Considerable modification of plant would be involved in fitting this process into existing installations.

Corrosion Tests on Tin-Nickel Alloy and Nickel/Chromium Coatings

S. C. BRITTON and R. M. ANGLES: 'Tin-Nickel Alloy and Nickel/Chromium Coatings: Some Comparative Corrosion Tests.' *Chemistry and Industry*, 1952, Nov. 22, p. 1152.

Short abstract of paper presented at joint meeting of the Corrosion Group of the Society of Chemical Industry and the London Section of the Institute of Metal Finishing, Oct. 20, 1952. Report of comparative exposures on plated steel and brass specimens, outdoors in four localities, and also indoors. 'The tin-nickel coatings remained bright in all the tests, but the

formation, in outdoor exposure, of small hard mounds of corrosion product of the basis metal at pores in the coating produced spots which became difficult to remove by simple cleaning. The chromium coatings soon fogged, especially when sheltered from rain and not cleaned, by corrosion products from the basis metal. This stain, however, was more easily removed by cleaning than were the spots forming at pores in the tin-nickel coating.'

See also—

S. C. BRITTON and D. G. MICHAEL: 'Tin-Nickel Alloy Coatings: Estimation of Thickness and Porosity.' *ibid.*, pp. 1152-3.

'Solution of the alloy by immersion in concentrated phosphoric acid at 180°C. or by anodic treatment at 300 amp. per sq. ft. in 10 per cent. hydrochloric acid provided means of estimating the thickness of coatings on brass or copper. These agents could also be used for deposits of the alloy applied, as they often were, over a copper undercoat to steel. Neither these agents nor any others tested were capable of removing deposits applied direct to steel without serious solution of the basis metal. A magnetic instrument has been found suitable for measurement of such coatings. An attempt to refine Mesle's chord method yielded results which were always too low. For the estimation of porosity of coatings on steel, the ferricyanide test was found to give good results only if the samples were first cleaned cathodically. Salt-spray tests did not reproduce behaviour observed out of doors, and the hot-water test failed to produce sufficiently conspicuous spots. Exposure of samples over a dilute solution of sulphur dioxide for 24 hours, followed by brief exposure to ammonia, produced rust spots at pores similar to those formed in a long period out of doors.'

Discussion of the papers, which is briefly reported, included reference to anodic stripping of tin-nickel in a solution containing ammonium bifluoride, sulphuric acid and ferric chloride. Some favourable experience of the behaviour of tin-nickel coatings in indoor service was reported.

Increasing Throwing Power of Nickel-Plating Baths by Use of Sulphites

H. KOMUSAARI: 'Improving the Properties of Nickel-Plating Baths, especially their Throwing Power, by Means of Sulphurous Acid or Sulphites.' *Metalloberfläche*, 1952, vol. 4, Nov., pp. B 162-3.

In the course of plating reflectors in a bath which had been freshly lined with Neoprene it was observed that at points of low current density either the coating was dark or there was no deposit. Treatment of the bath with nickel carbonate and with activated carbon resulted in elimination of the dark patches, but did not improve the throwing power, and after additions of hydrogen peroxide and potassium permanganate even larger areas were left unplated.

Addition of 5 g. sodium sulphite per litre effected, however, an astonishing improvement in throwing power, but the brightness of the deposit suffered badly. Reduction of the amount of addition medium to 30-100 mg. SO_2 per litre, in the form of sulphite, proved, however, to give adequate correction of throwing power, without deleterious effect on brightness. The writer reports that, acting on these experiments, he is now systematically using sulphite additions. Such treatment has also proved to have a beneficial influence in reducing hydrogen porosity and lowering the stress in the deposits. The disadvantage of a sulphite addition is that it makes precipitation of iron from the bath more difficult, by hindering transformation to trivalent iron, and causes turbidity which is difficult to eliminate. The composition of the nickel bath involved is given as (g./L.) nickel sulphate 200, nickel chloride 40, magnesium sulphate 35, boric acid 25, plus saccharin, a brightener, and cleansing media. Artificial polyvinyl chloride is used for the anode bags.

Properties of Electrodeposited Nickel: A.E.S. Report: Corrected Data

'Physical Properties of Electrodeposited Metals. I. Nickel. 3. The Effect of Plating Variables on the Structure and Properties of Electrodeposited Nickel.' *Plating*, 1952, vol. 39, Nov., pp. 1229-30.

Errors occurred in captions of some of the figures in the A.E.S. Research Report published in the August 1952 issue of *Plating* (see *Nickel Bulletin*, 1952, vol. 25, No. 11, p. 258). The figures affected are now re-published, with correct captions, and an additional figure is given, to correspond with the text. The revised information is supplied on a detachable sheet, for insertion in the original report.

Cast Nickel Anodes

E. R. THEWS: 'The Production of Cast Nickel Anodes.' *Metal Finishing*, 1952, vol. 50, Dec., p. 69.

Note commenting on article published *ibid.*, Sept., 1952; see *Nickel Bulletin*, 1952, vol. 25, No. 11, p. 259. The information given in the article should be taken as referring only to European practice and opinion, since it does not accurately represent procedure and views in the U.S.A.

Coatings for Use in Various Types of Atmosphere: D.I.N. Schedules

G. SCHIKORR: 'Supplement 1 to Tentative Standard Specification D.I.N. 50 960.' *Werkstoffe und Korrosion*, 1952, vol. 3, Sept., pp. 428-32.

Following the issue of earlier specifications covering thickness of coating, methods of test, etc. (see *Nickel Bulletin*, 1952, vol. 25, No. 2, p. 41), Deutscher Normenausschuss has published notes on coatings recommended for use in specific atmospheres. Section 1 of the schedule describes the nature of the attack involved in exposure in (*a*) interior locations, (*b*) outdoor conditions in inland areas, (*c*) marine atmospheres. A tabular summary is then made (in comparison with steel) of average rates of corrosion of coatings of lead, cadmium, copper, nickel, zinc and tin, in country, industrial, and marine atmospheres likely to be encountered in Central and Western Europe. This is followed by recommendations on the thicknesses considered adequate, under various conditions, when using coatings of lead, chromium,

cadmium, copper and copper alloys, nickel, zinc, tin. A brief note is added on the conditions in which bare steel or iron may be expected to give reasonable resistance to atmospheric corrosion.

Nickel Plating of Plastics

'Direct Plating on Plastic.'
Metal Industry, 1952, vol. 81, Nov. 21, p. 406.

When plating phenolic materials it has until now been necessary to produce on the surface a conductive coating, prior to electrodeposition. A new plastic, developed under the name of Durez 15615 Black, is now announced which, it is claimed, can be directly plated from acid baths of copper, nickel, and zinc. No sensitizing or silvering is required, and the bond between plastic and metal coating is stated to be strong. Brief notes are given in this article on conditions required for plating (1) mouldings having plain or curved surfaces and few sharp edges, and (2) intricate shapes containing surfaces which are difficult to reach with a buffing wheel, or pieces of intricate surface design. The new plastic is made by Durez Plastics and Chemicals, Inc., North Tonawanda, New York.

Nickel Plating of Stainless Steel Prior to Brazing

A. KORBELAK and E. C. OKRESS: 'Plating as an Aid in the Brazing of Stainless Steel.' *Plating*, 1952, vol. 39, Nov., pp. 1220-2, 1228.

The article describes methods devised to facilitate brazing of the parts of an electronic unit, in which size and intricate design precluded the use of conventional vacuum furnace techniques. The procedure used, after cleaning of the basis metal, was a preliminary strike from a chloride bath, followed by nickel plating from a Watts-type solution, in which precautions were taken against pitting, by addition of a specially stabilized grade of hydrogen peroxide. Current densities of the order of 25 amp./sq. ft. (2·6 amp./sq. dm.) were used. A table in the paper gives guidance as to the thickness of deposit required to ensure satisfactory behaviour for brazing conditions varying in temperature and length of time involved.

By the use of the plating cycle described, it has been found possible to put on a production basis the joining of large stainless-steel parts by simple commercial hydrogen-brazing procedures with nominal or usual dew points of the order of +250°C., employing brazing alloys such as silver-copper eutectic, Silfos, gold-copper, etc.

Rapid Analysis of Nickel-Plating Solutions

I. GOLDMAN: 'Nomogram for Analysis of Watts-Type Nickel-Plating Solutions.' *Metal Finishing*, 1952, vol. 50, Nov., pp. 76-7.

The nomogram, which is accompanied by descriptive notes, is based on fixed sizes of sample and on titrant concentrations generally used. Technique for the use of the nomogram is explained in a simple calculation superimposed on the chart.

NON-FERROUS ALLOYS

Optical Characteristics as Related to Crystal Orientation in Monel

H. C. VACHER: 'A Correlation of Polarized Light Extinctions with Crystal Orientation in 70 Nickel-30 Copper Alloy.' *Jnl. Research, Nat. Bur. Standards*, 1952, vol. 49, Sept., pp. 149-53; R.P. 2351.

Previous work at the National Bureau of Standards had shown that the surface of isotropic Monel was optically anisotropic after the surface had been polished electrolytically and etched with 'Monel contrast solution' (*Trans. Amer. Inst. Mining and Metallurgical Engineers*, 1949, vol. 185, pp. 722-6; *Nickel Bulletin*, 1949, vol. 22, No. 12, p. 194). It was noted that extinctions obtained at normal incidence, with crossed nicols, were not uniform over a grain in a specimen which had been deformed plastically, as was the case for a grain in an annealed specimen. This non-uniform extinction of individual grains was interpreted as indicating differences in orientation resulting from inhomogeneous strain. In view of the brilliant contrast of the grains and sharpness of the extinctions, it was considered that polarized light might be useful in determining the orientation of individual crystals, and the study described in the present paper was therefore undertaken.

After etching a specimen of the alloy to produce an optically anisotropic surface, the orientations of twelve crystals were determined by the twin-boundary method, and the positions of polarized-light extinctions (obtained at normal incidence with crossed nicols) were measured. Comparison of the orientations with the positions of the extinctions showed that one was near the cubic pole farthest from the surface normal. Little or no extinction was obtained when a (100) or (111) plane was nearly parallel to the surface. Study of the results indicated that the optical anisotropy observed in the earlier experiments was caused by parallel furrows formed by the action of the etching reagent. This tended to develop etch pits, the facets of which were parallel to cubic planes.

Cupro-Nickel Alloys containing Iron

See abstract on p. 27.

Corrosion by Water: Effects of Velocity

See abstract on p. 23.

Copper-Nickel-Silicon Alloy Resistant to Stress-Corrosion

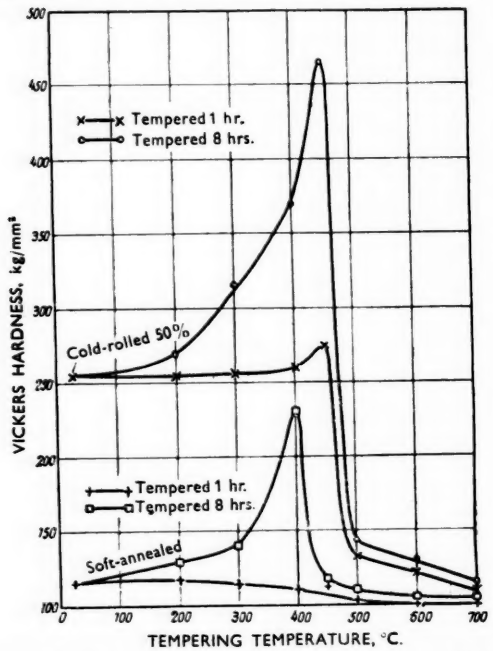
See abstract on p. 27.

Temper-Hardening of Copper-Manganese-Nickel Alloys

O. DAHL and K. L. DREYER: 'Contribution to the Study of the Hardenability of Copper-Manganese-Nickel Alloys.' *Metall*, 1952, vol. 6, Dec., pp. 753-5.

The authors report a study of the alloy containing copper 60, manganese 20, nickel 20, per cent., referred to in *British Patent* 658,264 as showing particularly good response to temper hardening. Tempering

treatments (200°-700°C. for one or eight hours) were applied to sheet in (*a*) the soft-annealed condition produced by heating for an hour at 800°C., and (*b*) in the cold-rolled condition (50 per cent. reduction, with intermediate annealing). The curves below show the hardnesses obtained after the respective tempering treatments, on both series of alloys.



Change in Hardness of Soft-annealed and of Cold-worked Copper-Manganese-Nickel Alloy (20% Mn, 20% Ni) as a Function of Tempering Temperature.

In commenting on these results, comparison is made with temper-hardening effects characteristic of other alloys. Attention is called to the fact that in the copper-manganese-nickel alloys investigated the incubation period, both in the annealed and the cold-worked specimens, is unusually long, at least one hour. Also, whereas in most temper-hardening alloys fall in hardness occurring after passing the maximum is gradual, in the copper-manganese-nickel alloys the drop is sharp. The authors consider that the change occurring in these alloys is not the usual type of temper-hardening, but that there is a transformation or ordering effect in the crystal lattice. This matter may be the subject of further study.

A series of photomicrographs illustrates structures produced by eight-hour treatment at various temperatures within the range 300°-500°C. They indicate that when the alloy is tempered from the soft-annealed condition there is a tendency to discontinuous breakdown: it remains to be determined whether it is a case of precipitation of the type found in copper-silver alloys, or whether there is a separation into two solid solutions, as with gold-nickel alloys. The copper-manganese-nickel alloy tempered after cold working shows discontinuous breakdown when the tempering temperature is relatively low, but when treated at temperatures above 300°C. continuous precipitation occurs, and not only the crystal boundaries, but also slip planes and other 'interruption' points act as nuclei. In both the alloys tempered from the annealed condition and those treated in the cold-worked state, maximum hardness is associated with the highest degree of heterogeneity.

Electrolytic Manganese: Use in Nickel-containing Alloys and Steels

R. S. DEAN: 'Electrolytic Manganese and its Alloys.' *Published by Ronald Press Co.*, New York, 1952; 257 pp. Price 96/-.

The book is 'a record of the progress of the art of electrolytic production of manganese and the development of its uses since 1936, when a practical method for production of electrolytic manganese from U.S. ores was developed, under the direction of the author, at the U.S. Bureau of Mines.'

In addition to full details of production methods (chapter 1), the author describes alloys in which electrolytic manganese produces properties significantly different from those of similar alloys made with other grades of manganese. The principal manganese alloys at present in production are the high-expansion type (manganese 72, copper 18, nickel 10, per cent.); the age-hardening alloy (copper 60, manganese 20, nickel 20, per cent.); the alloy of high damping capacity (manganese 80, copper 20, per cent.), and the low-expansion alloy (manganese 50, iron 45, aluminium 5, per cent.). The properties and uses of these materials, of the 5 per cent. manganese-nickel sparking plug alloy, and of other manganese alloys, are covered in chapter 2, and chapter 3 deals with ferrous alloys of electrolytic manganese, in which its use promotes higher ductility than is obtained with other grades.

Order-Disorder and Related Phenomena in Nickel-Chromium Alloys

A. TAYLOR and K. G. HINTON: 'A Study of Order-Disorder and Precipitation Phenomena in Nickel-Chromium Alloys.' *Jnl. Inst. Metals*, 1952-53, vol. 81, Dec., pp. 169-80.

It has been known for some time that alloys based on Ni_3Cr display a marked anomaly in their electrical resistance-temperature curves. On the basis of differential cooling curves and measurements of specific heat, this anomaly has been tentatively ascribed, *inter alia*, to an order-disorder type of transformation. The shape of the resistivity-temperature curve is not, however, of the form normally associated with this type of transformation, and early X-ray diffraction studies failed to reveal superlattice lines consistent with an ordering process in the crystal lattice.

The work reported in the present paper forms part of an extensive series of X-ray, electrical-resistivity and specific-heat studies on nickel-chromium and nickel-chromium-aluminium alloys. The measurements described were made on Ni_3Cr and $Ni_{15}Cr_4Al$.

In general, the results confirm the view that the anomalous variations in electrical resistance are

associated with an order-disorder type of transformation. The chief evidence for the formation of a highly ordered structure in the binary alloy Ni_3Cr is supplied by specific-heat measurements. Confirmatory specific-heat and X-ray evidence is derived from the ternary alloy $Ni_{15}Cr_4Al$, which gives superlattice reflections of appreciable density in its Debye-Scherrer X-ray-diffraction pattern. It is shown how the creation of new sets of reflecting planes by the ordering process may lead to a small increase in resistivity if the mean free path of the conductivity electrons is of the order of a few interatomic distances. Above the critical temperature for ordering, the resistivity and specific-heat curves of $Ni_{15}Cr_4Al$ display a number of inflections which are not revealed by Ni_3Cr. These inflections have been shown to be associated with the precipitation, crystal growth, and re-solution of a fully ordered face-centred cubic structure based upon the Ni_3Al phase of the nickel-aluminium binary system.

Nickel-Lanthanum Alloys: Magnetic Properties

J. WUCHER: 'The Magnetic Properties of Nickel-Lanthanum Alloys.' *Jnl. de Physique et le Radium*, 1952, vol. 13, pp. 278-82; *Physics Abstracts, Sect. A*, 1952, vol. 55, Oct., p. 894; Abs. 7391.

'The two metals form solid solutions up to 9 per cent. lanthanum, the Curie temperature decreasing linearly up to this concentration and extrapolating to zero at 20 per cent. lanthanum, but remaining constant at about 350°K. (77°C.) above 9 per cent. lanthanum. Paramagnetic measurements on several intermetallic compounds ($Ni_\nu La$, $\nu = 5\text{-}1$; $NiLa_3$) are also reported and the moment of the nickel ions is deduced from the measurements where possible.'

Oxidation Characteristics of Nickel- and Cobalt-Base Alloys at High Temperatures

See abstract on p. 20.

High-Temperature Mechanical Properties of Intermetallic Compounds

See abstract on p. 18.

Nickel-Zinc Alloys

F. LIHL: 'Contribution to the Study of the Nickel-Zinc System.' *Zeitsch. für Metallkunde*, 1952, vol. 43, Sept., pp. 310-12.

Report of precipitation-hardening experiments on a series of nickel-zinc alloys (0-40 per cent. zinc) produced by sintering of nickel powder and powdered nickel-zinc alloy containing 70-80 per cent. zinc. The observations made lead the author to the conclusion that the zinc-solubility limit of the α solid solution must lie at considerably higher nickel contents than those recorded on the constitutional diagram developed by W. HEIKE and J. SCHRAMM (*Metallwirtschaft*, 1932, vol. 11, pp. 525, 539 ; 1933, vol. 12, p. 115). X-ray examination of an alloy powder produced from nickel-zinc amalgams confirmed this finding, in that in the equilibrium condition at 300°C. the α solid solution is capable of retaining in solution only 7-8 per cent. of zinc, i.e., an amount of the same order as that found in the iron-zinc system. It can be safely assumed that at room temperature the solubility of zinc in nickel is still lower.

Zirconium-Nickel Alloys

S. M. SHELTON: 'Zirconium Alloys for High-Temperature Service.' *U.S. Air Force, Air Matériel Command, A.F. Tech. Rept.* 5932, June, 1949: 73 pp.

Report on investigation of the zirconium-rich end of 25 alloy systems, with a view to development of alloys suitable for high-temperature service. Most of the systems studied were binary.

Tests made by exposure in air showed that none of the alloys investigated could be considered for service above 1400°F. (760°C.): many of them practically disintegrated at 1200°F. (650°C.). In the zirconium-nickel series alloys containing up to 8 per cent. of nickel were used: details are given of microstructure, hardness, forgeability, heat-resistance and tensile properties (at room temperature and at 1200°F.:650°C.).

Polarographic Determination of Nickel in Aluminium Alloys

See abstract on p. 5.

NICKEL-IRON ALLOYS

Magnetic Powders: Production, Properties, Uses

G. R. POLGREEN: 'The Production and Application of Magnetic Powders.' *G.E.C. Journal*, 1952, vol. 19, July, pp. 152-69.

This article describes methods and equipment developed by The General Electric Company, Limited, and its associate, Salford Electrical Instruments, Limited, for the manufacture of iron, nickel-iron alloy, and other powders, and discusses the properties and uses of the materials regularly produced. Most of the magnetic powder now being made is used for low-loss cores for telephony and radio, but there have also been recent important advances in new powder cores for such diverse applications as indicating instruments, television transformers and scanning coils, and fluorescent lighting chokes. Other types of powder now produced have properties which render them highly suitable for permanent-magnet applications.

Following discussion of the characteristics required in magnetic materials, and the properties of powder cores, a critical review is made of the four principal methods used for production of magnetic powders: the electrolytic process, mechanical disintegration, the carbonyl process, and chemical-reduction methods. An account is then given of the technique developed in the G.E.C. Research Laboratories for production of iron and alloy powders by chemical reduction with hydrogen, and of the equipment and technique employed in applying this process on a commercial scale. Details are given of the reduction, grinding, sifting, and purification stages involved in manufacture of the powders, and of insulation methods employed in

core production. Tests used on the powders are also discussed, and the stages of production of the actual cores are described.

In reviewing new developments in powders, particular reference is made to (1) the useful properties of very pure iron, (2) a new copper-nickel-iron powder (Gecalloy III), from which it is possible to produce cores having higher permeability and lower losses than cores made from any other alloys now being manufactured, (3) new grades of iron powder, and (4) a 50-50 nickel-iron alloy, which in fine size provides a high-permeability low-loss material for radio cores, and in coarser form is used for power applications. Attention is also directed to magnetic iron-oxide powder now being used in magnetic-tape recording and for some types of magnet. The review closes with a short section indicating some of the applications of the new materials in electromagnetic equipment.

Behaviour of Nickel-Iron Alloys under Current Pulse Conditions

E. A. SANDS: 'The Behaviour of Rectangular Hysteresis Loop Magnetic Materials under Current Pulse Conditions.' *Proc. Inst. Radio Engineers*, 1952, vol. 40, Oct., pp. 1246-50.

In connexion with the use of thin-ribbon magnetic toroids in digital computers, attention has been directed to materials characterized by a rectangular hysteresis loop, because they have two stable, well-defined states of positive and negative residual flux density for storing binary information. Suitable materials for the purpose are cold-rolled 50-50 nickel-iron and oriented silicon steels. In this paper a study is made of the effect of variation of magnetic and physical parameters on the time needed to change a magnetic toroid from a condition of residual flux density to the opposite condition of saturation flux density. The method of measurement is described, and experimental results obtained by it on cores of Orthonik (nickel-iron alloy) are given. They are compared with results predicted from a solution of the magnetic skin-effect equation. Curves show variation of switching time with applied magnetic field strength, the term 'switching time' being used to denote the time required to change the state of magnetism of a core from negative residual flux density ($-B_R$) to positive saturation flux density ($+B_M$), with the application of a step function of applied field strength (H_M). The factor which determines switching time is eddy-current losses.

CAST IRON

Mechanical Properties of S.G. Iron

C. F. REYNOLDS and H. F. TAYLOR: 'Mechanical Properties of Spherulitic-Graphite Cast Iron.' *Trans. Amer. Foundrymen's Assocn.*, 1952, vol. 60, pp. 687-713.

This paper, presented at the International Foundry Congress in May, 1952 (but not preprinted), reports research carried out at the Massachusetts Institute of Technology, on behalf of Watertown Arsenal, U.S.A. The investigation, which was of a comprehensive character, is reported under the following headings:—

(1) Effect of variations in melting practice.
(2) Efficacy of known methods of introducing the addition medium.
(3) Types of magnesium alloy giving best results.
(4) Influence of composition.
(5) Effect of heat-treatment.
(6) Effect of section size.
(7) Correlation between microstructure and properties.

Induction-furnace melting was used, and it was established that the most satisfactory results were obtained by employing a nickel-magnesium addition alloy. Mechanical properties were studied on as-cast and on annealed irons, in the following range of composition: carbon 2·26-4·0, silicon 1·39-4·38, manganese 0·033-2·13, phosphorus 0·026-0·800, sulphur 0·017-0·09, per cent. Particular attention was given, in the compositional studies, to the influence of high phosphorus on liquid shrinkage, and on expansion, or growth, of the castings on solidification. The influence of variations in composition on matrix structure, and on quantity and size of spheroids, as well as on mechanical properties, is recorded.

The results of mechanical tests in the various series are shown graphically, and the paper contains many illustrations of typical castings and their microstructure. Considerable attention is given to study of conditions necessary for full ferritic annealing, and data on effect of composition on pearlite breakdown are included.

Among the conclusions drawn from the highly detailed results recorded are the following:—

Tensile and yield properties of as-cast material fall with increase in section size; the drop is sharp at first ($\frac{1}{2}$ in.-1 in.) and subsequently more gradual (1 in.-4$\frac{1}{2}$ in.). Hardness values follow strength properties closely, in relation to section. Microstructure gives a good indication of quality and properties, and strength and ductility can be gauged from the proportions of pearlite and ferrite present.

With regard to composition, it is found that nickel, silicon, manganese, and phosphorus all contribute to the mechanical properties of annealed S.G. iron, by their solid-solution effect on ferrite. Their effects on as-cast structure depend on their influence on the matrix, through carbide stabilization. Optimum composition for a high-ductility, ferritic S.G. iron is considered to be carbon 2·8-4·2, silicon 1·5-4, manganese 0·25-0·75, phosphorus 0·25 max., sulphur 0·06 max., per cent.

The properties of S.G. iron having good graphite structure are believed to be independent of the method of production of the iron, except as influenced by incidental and alloy elements introduced in treating the metal.

An appendix to the paper contains details of methods of chemical analysis and mechanical testing used. The paper concludes with a *bibliography* of 354 references to the literature of S.G. iron.

S.G. Iron Gears

C. GALLETTO: 'Production of Heavy Gear Wheels in Spheroidal-Graphite Cast Iron.'
Trans. Amer. Foundrymen's Assocn., 1952, vol. 60, pp. 223-8.
*Reprint issued by International Nickel Co., Inc.**

The paper describes the production, in S.G. iron, of large gear wheels, by an Italian foundry, G. Tagliabue and Company, of Milan. Small castings are made from melts produced in electric-resistor furnaces, whilst large castings are made from cupola- or electric-arc furnace iron, or from a mixture of both. The as-cast S.G. iron made from the electric-furnace material gives a tensile strength of 41-45 tons per sq. in., with an elongation of 3-5 per cent., and a Brinell hardness of 220-230. Castings from the cupola show a tensile strength of 45-48 tons per sq. in., with 4-5 per cent. elongation, and hardness of 240-250.

The method of moulding the teeth on large gears is described and illustrated.

The gear wheels, which are used as-cast, are being successfully employed in cement kilns, grinding mills, mixers for rubber and ceramics, hoisting equipment and other applications.

Ductile Iron in Water Works Equipment

C. T. HALLER: 'Ductile Iron: A New Engineering Material for Water Works Construction.'
Reprint from Jnl. Amer. Water Works Assocn., 1952, vol. 44, Oct., pp. 912-22.
Issued by International Nickel Co., Inc.†

The paper opens with a short discussion of the structure and properties of S.G. iron, and refers briefly to its industrial development. In considering applications, extensive reference is made to S.G. iron pipe, a large tonnage of which has already been produced, although its use is still in the experimental stage. Particular interest is associated with the high bursting strength and ductility of S.G. iron pipe, which can be considered for use (*a*) in the same dimensions as grey-iron piping, where higher strength and resistance to bursting are required, or (*b*) where wall thickness can be reduced, with consequent reduction in weight, lessening of transport costs, and greater ease of handling. Calculations based on U.S. specifications show that, for any given class of pipe or working pressure, the metal in the pipe wall can be much reduced by using S.G. iron, and that even with such reduction a greater factor of safety could be employed. The author also discusses pipe fittings, giving results reported by Underwriters' Laboratories, Inc., on the basis of which S.G. iron fittings to the dimensions for malleable cast iron 150-lb. grading were accepted for 300-lb. service in water piping for sprinklers, sprayers and stand-pipe equipment. Other successful applications of S.G. iron mentioned are hydraulic press cylinders, pipe flanges, manhole frames and covers, valve-body assemblies, and fire hydrants. S.G. iron is likely to be more resistant than grey iron to graphitic corrosion, but normal corrosion tests in various common media indicate that in this respect there is not much difference between flake-graphite and S.G. irons.

Ni-Resist (High-Alloy) Corrosion-Resisting Cast Iron

INTERNATIONAL NICKEL CO., INC.: 'Engineering Properties and Applications of Ni-Resist.' (Third edn.)
Published by International Nickel Co., Inc., 1952; 36 pp.†

The trademark 'Ni-Resist' covers a group of high-nickel alloy cast irons with varying amounts of chromium, with or without copper. By reason of its high alloy content and resulting structure, Ni-Resist provides a unique combination of properties: resistance to corrosion and heat, strength and toughness, wear-resistance, good machinability, high electrical resistance, and (by suitable choice of the nickel content) non-magnetic characteristics, and high or low thermal expansion. These properties are individually discussed in this Bulletin, and an account is given of the many and varied applications for which the respective grades of Ni-Resist are suitable.

Ni-Resist Valves in Contact with Hydrochloric Acid Vapours

'Crane Ni-Resist Valves show Five to One Superiority.' *Nickel Topics*, 1952, vol. 5, No. 7, p. 3.

The note reports experience at the plant of Corn Products Refining Company, Argo, Illinois, in connexion with valves on raw-material inlet lines to starch converters. In this application the valves are exposed constantly to hydrochloric-acid vapours, at working pressures of 50 p.s.i. and temperatures averaging 280°F. (138°C.). The necessity for constant replacement had led to excessive maintenance costs and lowering of production. The problem has now been solved by the use of Ni-Resist (high-nickel alloy cast iron) for the bodies, bonnets and discs of the valves, with trim of 18-8-Mo chromium-nickel steel. At a recent inspection the valves were found to be in excellent condition after 19 months of uninterrupted service (five times longer than the life of units in any other materials used), and the indication was that they had still long service ahead. Valves of Ni-Resist are also successfully used in various other types of plant, for handling corrosive vapours, acid salt and alkaline solutions, sea water, hydrogen, sulphides and many other industrial corrosives.

Ni-Hard Liners in Rod Mill

'Ni-Hard Aids Rod Mill to Make Excellent Service Record.' *Nickel Topics*, 1952, vol. 5, No. 7, p. 5.

In 1948 the Consolidated Mining and Smelting Company of Canada, Limited, introduced into its Sullivan concentrator (handling lead and zinc ore) a large rod mill, which replaced two sets of 74-in. and 20-in. rolls, with their accompanying screens and conveyors. It has been found that, compared with the old roll installation, the new mill produces a finer product, suitable as feed for the primary ball mills. Barrel and end liners in the rod mill are of Ni-Hard, in order to obtain high resistance to wear. Justification for the choice of this material is provided by the fact

**Copies of this publication will shortly be available.*

†We shall be pleased to supply a free copy of this publication.

that the original liners are still in service after four years, and that a conservative estimate is that their total life will approximate 7,300,000 tons for barrel liners and 6,500,000 for the end liners. Some details are given of the capacity of the mill.

Ni-Hard Guides for Winding Winches

'Nickel-Chromium White Iron Outlasts Steel Ten to One.' *Nickel Topics*, 1952, vol. 5, No. 7, p. 7.

The note describes and illustrates guides used to control the movement of winch cables in loading and unloading barges. Experience with steel guides had shown that they lasted only three to four months, and that as they roughened and deteriorated they wore the cable badly. Bronze, cast iron, and manganese steel guides also proved unsatisfactory. An experimental installation of guides cast from a Ni-Hard type of cast iron was put into service in May 1949, and on removal of the first guide in March 1952 its condition was such that the user immediately specified to his manufacturer that only nickel-alloy cast iron guides should, in future, be supplied to him. The manufacturer has since changed his own specifications, to require that all guides of this type shall be made in the alloy iron.

Analysis of Iron and Steel

See abstract on p. 16.

CONSTRUCTIONAL STEELS

Formation of Bainite in Nickel-Alloy and Other Steels

T. KO and S. A. COTTRELL: 'The Formation of Bainite.' *Jnl. Iron and Steel Inst.*, 1952, vol. 172, Nov., pp. 307-13.

When austenite is isothermally transformed at temperatures in the intermediate range an acicular aggregate of ferrite and carbide particles forms, generally known as bainite. The structure and mechanism of formation of bainite have been extensively studied since publication of the classic paper by DAVENPORT and BAIN (*Trans. Amer. Inst. Mining and Metallurgical Engineers*, 1930, vol. 90, pp. 117-54). The mechanism of the reaction has not, however, been fully established, and it is with a further study of this fundamental aspect that the present paper is concerned.

Following a brief résumé of suggestions which have previously been made, the authors deal with three questions which they consider as still remaining unanswered:—

(i) Whether the austenite and bainite lattices are incoherent, as in the case of ferrite and austenite, or coherent, as in that of martensite and austenite.
(ii) Whether bainite forms, like ferrite and carbide, by nucleation and growth, or, like martensite, in a fraction of a second.
(iii) Whether there is really any fundamental difference in the mechanism of formation of 'upper' and 'lower' bainite.

These questions were studied on steels covering a wide range of composition, selected as representative of—

(i) steels which undergo complete transformation to bainite within a certain temperature range;
(ii) steels undergoing full transformation to pearlite after partial decomposition to bainite;
(iii) steels exhibiting separate pearlitic and bainitic ranges;
(iv) steels having a long incubation period and a low M_S point.

Steels so chosen included standard low-alloy chromium-molybdenum, chromium, nickel, and nickel-chromium-molybdenum types, and a high-carbon steel made in the h.f. induction furnace. Experimental methods of investigation are fully described.

From the observations made on the various types of steel (structures of which are illustrated by an extensive series of photomicrographs), the following conclusions are drawn:

'When bainite is formed from austenite the surface of the specimen is distorted, giving a structure similar to that obtained during formation of martensite. By studying the surface relief during formation of bainite, using a specially developed metallographic technique and hot-stage microscopy, it has been established that bainite forms by nucleation and coherent growth, the rate of which depends on the composition of the austenite and increases with rising temperature. The rate of growth is very slow compared with that of martensite.

'It is suggested that the free-energy difference between austenite and the supersaturated ferrite is not sufficiently large to allow the formation of martensite, owing to the adverse strain. Nevertheless, coherent growth can take place when the strain due to the density change is relieved, and the driving force for the transformation is increased if the amount of carbon dissolved in the bainite is reduced. This can be achieved either by carbon diffusion from bainite into the austenite, or by precipitation as carbide within the bainite plates, or by a combination of both.

'The present investigation has revealed a new type of transformation in which the coherent growth of a new phase is probably controlled by a diffusion process. It is suggested that the term 'coherent transformation' can be used for describing the processes by which both martensite and bainite are formed, in contrast with the incoherent precipitation of ferrite and cementite. The term 'martensite' should be used for the low-temperature phase when the process is coherent and diffusionless. When the process of coherent growth is controlled by diffusion, the product may be called 'bainite'.'

Temper-Brittleness in Low-Alloy Steel Weld Metal

R. P. WENTWORTH and H. C. CAMPBELL: 'Temper-Brittleness in Low-Alloy Steel Weld Metal.' *Welding Jnl.*, 1952, vol. 31, Nov., Suppl. pp. 505-14.

In connexion with the increased interest which has recently been taken in the heat-treatment of low-alloy steel weld deposits, the problem of susceptibility to temper-brittleness has come under consideration.

Type	C %	Mn %	Si %	Cr %	Ni %	Mo %	V %
120,000 p.s.i. 53·5 t.s.i. } Ni-Mo-V	0·054	0·70	0·16		1·52	0·88	0·20
100,000 p.s.i. 44·5 t.s.i. } Ni-Mo-V	0·058	0·49	0·27		1·73	0·53	0·07
2Cr—½ Mo	0·170	0·31	0·57	2·47		0·57	
Mn-Mo—low C	0·070	1·65	0·36			0·36	
Mn-Mo—medium C	0·170	1·76	0·27			0·33	

After reviewing some of the observations made by other investigators, on nickel-molybdenum-vanadium steel and other weld metal, the authors report a study of five low-alloy low-hydrogen electrode compositions as shown in the table above.

A slow notch-bend test was developed, to give a ductile or brittle (pass or fail) indication. By the use of two criteria (fracture appearance and per cent. contraction in width of specimen under the notch) it was possible to study isothermal development of temper-brittleness. The results showed susceptibility to temper-brittleness in the two nickel-molybdenum-vanadium steels, less serious in the 100,000 p.s.i. grade than in the higher-tensile grade; no susceptibility was found in the other three types of steel. It is concluded that:—

'The 120,000 p.s.i. nickel-molybdenum-vanadium steel should not be used if tempering of the as-welded or quench-hardened deposit is to be done in the range 1050°-1150°F. (565°-620°C.). If tempering at higher temperatures (1250°-1300°F.: 675°-705°C.) is permitted, this steel can, however, be used, with the following precaution: the metal should be held at 1250°F. (675°C.) for at least 4 hours, or at 1300°F. (705°C.) for at least 2 hours. A reduction in strength of 10,000-20,000 p.s.i. will result from such treatment.

'Slow cooling of the 120,000 p.s.i. grade can be permitted from the 1300°F. (705°C.) treatment (and probably also after tempering at 1250°F. (675°C.) if the tempering has been sufficiently prolonged). Better results may, however, be obtained by subjecting the material to a prior austenitizing heat-treatment.

'The 100,000 p.s.i. nickel-molybdenum-vanadium steel may be tempered in the range 1050°-1150°F. (565°-620°C.) if not more than one hour at temperature is required. Tempering at higher temperatures results in very little embrittlement.

'Temper-brittleness was not observed in the manganese-molybdenum and 2¼ per cent. chromium-molybdenum steel weld metal, in the range 900°-1300°F. (480°-705°C.).'

See also—

P. P. PUZAK and W. S. PELLINI: 'Embrittlement of High-Strength Ferritic Welds.' *ibid.*, pp. 521-6.

This paper reports investigation of the effects of stress-relieving heat-treatments on low-hydrogen high-strength ferritic welds of the manganese-molybdenum and nickel-molybdenum-vanadium steel grades, with particular reference to changes, so introduced, which might affect the performance of welded joints. It was established that the manganese-molybdenum type is essentially unaffected by such treatments, but that the nickel-molybdenum-vanadium steel exhibits pronounced loss in notch toughness. This is attributed to precipitation of vanadium carbides (similar to age-hardening reactions) occurring at the temperature of stress-relief treatment. 'Overageing', resulting from prolonged holding at stress-relieving temperatures, completely restores notch-toughness, but the strength properties of the weld then fall considerably below the level of the as-deposited metal. It is concluded that nickel-molybdenum-vanadium steel welds of the types examined are not suitable for stress-relief heat-treatment.

Sub-Zero Notch Toughness of Nickel-Alloy Steels

W. B. SEENS, W. L. JENSEN and O. O. MILLER: 'Notch-Toughness of Four Alloy Steels at Low Temperatures.' *Reprint from Proc. Amer. Soc. Testing Materials*, 1951, vol. 51, pp. 918-28. *Issued by International Nickel Co., Inc.*, 1952.*

For abstract, see *Nickel Bulletin*, 1952, vol. 25, Nos. 8-9, p. 210.

Transition from Ductility to Brittleness in Pressure-Vessel Steels

T. N. ARMSTRONG, N. A. KAHN and H. THIELSCH: 'Transition from Ductile to Brittle Behaviour in Pressure-Vessel Steels.'
Reprint from Welding Jnl., 1952, vol. 31, Aug., Suppl. pp. 371-80.
Issued by International Nickel Co., Inc., 1952.†

Critical review of available information, prepared under the aegis of the Pressure Vessel Research Committee, Welding Research Council. The survey, which is intended primarily as an interpretive engineering statement, is amplified by a *bibliography* of about 100 references to the major literature. Individual sections of the report cover the nature of brittle behaviour, tests used for evaluation of brittleness, the effects of temperature and the transition-temperature criterion, effects of notches, and notch-sensitivity.

* *Copies of this publication will shortly be available.*

† *We shall be pleased to supply a free copy of this publication.*

Factors determining transition temperatures are reviewed, including discussion of those of a metallurgical nature (effects of composition, homogeneity, grain size, straining and ageing, and heat-treatment), and mechanical factors (the stress system, design, workmanship, and welding). Some suggestions are made as to further investigation of the subject.

Electrolytic Manganese: Use in Nickel-containing Alloys and Steels

See abstract on p. 10.

Use of Nickel-Manganese-Molybdenum-Silicon High-Tensile Steel in Aircraft

C. H. STEVENSON: 'High-Tensile Steels. Application of New Higher-Strength Material in Aircraft Construction.' *Aircraft Production*, 1952, vol. 14, Dec., p. 411.

This short article describes the properties and uses of Hy-Tuf steel, a high-tensile material made by the Crucible Steel Company of America to the nominal composition: carbon 0·25, manganese 1·30, silicon 1·50, nickel 1·80, molybdenum 0·40, per cent. In order to realize its useful properties, the steel must be employed in the heat-treated condition, in which it shows a tensile strength of 220,000-240,000 p.s.i. (98-107 tons per sq. in.), with elongation of 13-14 per cent. It is a deep-hardening steel, a peculiarity of which is the very low tempering temperature required (not above 650°C.). This feature imposes a restriction on the temperature at which the steel can be used in service.

Experience at the Douglas Aircraft Company's plant (where Hy-Tuf is being used on landing-gear assemblies, catapult hooks, arresting hooks, etc.) shows that machining before heat-treatment presents no difficulties, but that in the hardened condition it requires twice the time which would be needed for machining many other heat-treated steels. The maximum amount of machining possible should, therefore, be done before the hardening treatment is applied. Straightening, and minor forming, of Hy-Tuf can be accomplished cold without difficulty: for hot forming somewhat higher temperatures are required than would be used for other low-alloy steels. The steel can be satisfactorily flash-welded by techniques generally used for alloy steels. It has not yet been found possible to develop a method which will give consistently good results in gas welding, but success has been achieved in metallic-arc welding, using coated rods. Following experience with the use of Hy-Tuf on experimental aircraft, the Douglas Aircraft Company is now introducing it on models entering the production stage.

Precipitation-Hardening Nickel-Chromium Steels in Aircraft Construction

See abstract on p. 26.

Rotating Discs for Aircraft Gas-Turbine Rotors

See abstract on p. 17.

Limiting Creep and Stress-Rupture Values for Nickel-containing Materials

See abstract on p. 17.

Welding of Nickel-containing Steels

E. FUCHS and H. BRADLEY: 'Welding Practice. Vol. II. Welding of Ferrous Metals.' *Published by Butterworths Scientific Publications*, in association with Imperial Chemical Industries, Ltd., 1952. 198 pp. Price 22/6.

The scope of this series of handbooks, and its arrangement, are described in the abstract of volume III: see *Nickel Bulletin*, 1952, vol. 25, No. 6, p. 150. In volume II, also, chapters on welding of individual materials are built up on a common framework, covering metallurgical factors affecting welding, guidance for welding designers, welding materials, workshop practice, and special applications of welding.

The chapters deal, respectively, with

Mild Steel Welding by the Metal-Arc Process.
Mild Steel Welding by Processes other than the Metal Arc.
Welding of High-Tensile Low-Alloy Steels.
Welding of Chromium-Nickel Austenitic Steels.
Welding of Cast Iron.
Weld Details for Pressure Vessels.
Hard Surfacing by Welding Methods.

A glossary of terms common to the subject matter of all the volumes is included.

U.S. Government Specifications for Alloy Steels

'Comparative Specifications for Alloy Steels.' *Materials and Methods*, 1952, vol. 36, Oct., pp. 153, 155, 157.

Tabular summary of specifications for low-alloy steels.

U.S. Military, U.S. Army, U.S. Navy, U.S. Army-Navy Aeronautical, and Federal schedules are included.

Analysis of Iron and Steel

BRIT. STANDARDS INSTN.: 'Methods for the Analysis of Iron and Steel. Part 27: Vanadium in Carbon and Low-Alloy Steels.' *B.S.* 1121: Part 27.

The sample is dissolved in phosphoric-sulphuric acid and the iron is oxidized with nitric acid. The vanadium is oxidized to vanadic acid at atmospheric temperature, by means of potassium permanganate. The excess reagent is destroyed by addition of sodium nitrite, and the oxidized vanadium is reduced with excess of ferrous ammonium sulphate. This is back-titrated with standard potassium dichromate solution, using barium diphenylamine sulphonate indicator.

Range: Up to 1·0 per cent. vanadium.

The alloying elements normally present in low-alloy steels do not interfere except at very low vanadium contents. In the latter case a mercury-cathode separation is recommended.

Part 28. 'Graphitic and Combined Carbon in Pig and Cast Iron.'

Determinations of total and graphitic carbon are carried out separately and the combined carbon is calculated by difference. The total carbon is determined by combustion, using a procedure similar to that described in B.S. 1121: Part 11, 'Determination of Carbon in Steel and Low-Carbon Ferro-Chromium.' For the determination of graphitic carbon the

sample is decomposed by treatment with nitric acid and the residual graphite is filtered off and washed. The residue is then ignited in a stream of oxygen and the carbon dioxide is absorbed and weighed as in B.S. 1121: Part 11.

Range: Up to 4½ per cent. carbon. The method has been employed on plain and alloy irons, with satisfactory results.

HEAT- AND CORROSION-RESISTING ALLOYS

Limiting Creep and Stress-Rupture Values for Nickel-containing Materials

'Limiting Creep and Stress-Rupture Values for Various Ferrous and Non-Ferrous Materials in Sheet Form.' *Materials and Methods*, 1952, vol. 36, Dec., pp. 139, 141, 143.

Tabular summary adapted from report by G. J. GUARNIERI and J. SALVAGGI, Cornell Aeronautical Laboratory, Inc., for Project Squid, sponsored by the U.S. Navy and U.S. Air Force.

Materials for which reference data are presented include plain, and low- and high-alloy steels (*inter alia*, various standard austenitic nickel-chromium steels), Stellite 25, N-155 Multimet, and Inconel X.

Rotating Discs for Aircraft Gas-Turbine Rotors

A. G. HOLMS and A. J. REPKO: 'Correlation of Tensile Strength, Tensile Ductility, and Notch Tensile Strength with the Strength of Rotating Discs of Several Designs in the Range of Low and Intermediate Ductility.' *Nat. Advisory Committee for Aeronautics, Tech. Note* 2791, Sept., 1952; 30 pp.

Reduction of disc weight for aircraft gas-turbine rotors is desirable for many reasons. Reduction in rotor weight has an amplified beneficial effect on total weight, because lower gyroscopic forces associated with lower rotor weight permit weight reductions for bearings, shaft, and frame. A small saving in disc weight thus permits a general saving of weight and materials throughout the engine. Use of high-tensile materials presents the possibility of reducing wheel thickness, and thus of reducing disc weight, while maintaining a given factor of safety. The investigation reported in this paper was made to examine some of the factors which limit the extent to which disc strength can be increased by increasing tensile strength, to determine the extent to which a correlation exists between disc strength and the several mechanical properties of materials at low ductilities, and to evaluate the influence, on disc strength, of several types of stress concentration, for ductile and brittle materials. The test materials used included chromium-molybdenum steel (4150 type), tool and die steels, Inconel X, age-hardenable 18-8 chromium-nickel steel, and beryllium-copper.

Order-Disorder and Related Phenomena in Nickel-Chromium Alloys

See abstract on p. 10.

Influence of Flaking-off of Scale in Accelerated Life Testing of Wires

W. BETTERIDGE: 'The Influence of Flaking of Scale on the Results of Accelerated Life Tests of Electrically Heated Wires.' *Paper to 4th International Congress of Industrial Heating*, 1952, Group 1, Section 16, Paper No. 18 ; 4 pp.

The suitability of wires for electrical-heating elements is usually assessed by an accelerated life test such as that described in A.S.T.M. Specification B76-39. With constant conditions of temperature and period of cycle the life of a wire in this test depends on two main factors: the rate of oxidation during the period at high temperature, and the degree to which cracking and flaking of the scale occurs on account of the fluctuation of temperature. The author reports tests on three different samples of 80-20 nickel-chromium wire containing varying amounts of calcium and/or cerium. The wires were tested by a modified procedure in which the wire alternated at intervals of 2 minutes between two temperatures, the upper one of which remained constant for a series of tests, whereas the lower one was varied from approximately normal temperature (the normal test) to the upper temperature (continuous heating). The results obtained indicate that the effect of small additions of certain elements which give considerably increased life in the normal test is primarily due to their influence on the adhesion of the scale to the metal.

Heat-Resisting Casting Alloys used in U.S.A.

G. F. GEIGER: 'Castings of Heat-Resisting Alloys Used in the United States of America; Properties and Applications.' *Paper to 4th International Congress of Industrial Heating*, 1952, Group 1, Section 16, Paper No. 146; 11 pp.

The paper is essentially of a review character, giving details of the alloys standardized by the Alloy Casting Institute. These fall into three groups: (1) high-chromium, low-nickel types (HC, HD); (2) iron-chromium-nickel (HE, HF, HH, HI, HK, HL), and (3) high-nickel-chromium (HT, HU, HW, HX). Much information is given, in tabular form, on the mechanical properties of these materials at room temperature and at elevated temperatures, and on their physical properties. To this are added condensed notes on fabrication, and a discussion of typical uses of the respective grades.

New High-Temperature Alloy: N.A. 22H

'New Alloy Tough in Hot Spots.' *Steel*, 1952, vol. 131, Nov. 17, pp. 90-1.

The article describes a new alloy developed by National Alloy Steel Division, Blaw Knox Company, for which the following composition is given as typical: carbon 0·44, chromium 26·3, nickel 46·0, manganese 1·36, silicon 0·99, tungsten 5·28, per cent. It is claimed that the alloy has properties superior to those of standard heat-resisting alloys over the range 1600°-1800°F. (870°-980°C.), and that it retains useful characteristics up to 2300°F. (1260°C.). A curve

shows results of cantilever creep tests, at 2200°F. (1205°C.) under a stress of 500 p.s.i., on 25-20 and 25-12 chromium-nickel-iron alloys, and on 35-15 and 67-17 nickel-chromium-iron alloys, in comparison with N.A. 22H. The new alloy is the only one of the five for which a straight-line relationship was found over the entire test of some 200 hours. Oxidation tests at 2200°F. (1205°C.), under cyclic conditions of heating and cooling, showed N.A. 22H to be highly resistant to deterioration. Thermal-expansion values are slightly lower than those of other comparable alloys, and with regard to resistance to thermal fatigue N.A. 22H may be assumed to be the equal of other commercial heat-resistant alloys. Applications in which it is already proving satisfactory include radiant tubes in continuous annealing furnaces, and retorts for endothermic gas generators.

Nickel-Chromium-Iron Alloys in Boiler Furnaces and Superheaters

J. H. JACKSON: 'High-Temperature Corrosion in Power Station Boiler Furnaces and Superheaters.'
Paper to 4th International Congress of Industrial Heating, 1952. Group 1, Section 16, Paper No. 144; 24 pp.

Steam temperatures of 550°C. are becoming usual in new central station boiler plants, and steam temperatures of 650°C. are expected in the relatively near future. Mercury-boiler units have operated these high temperatures for some time and mercury temperatures in the tubes of boiler furnaces have reached 590°C. The use of the high temperatures mentioned renders increasingly difficult the choice of materials of construction: both mechanical strength and scaling resistance fall with rise in temperature, and the position is complicated by the fact that many units are burning fuels which contain impurities highly deleterious to corrosion-resistance at high temperatures, e.g., sulphur and vanadium. The reports of conferences on which these problems have been considered are referred to by the present author, as an introduction to a review of research conducted at the Battelle Memorial Institute, which covered the performance of a group of heat-resisting alloys when exposed to the atmospheres of a number of different furnace units. Three investigations, of widely divergent nature, are discussed:—

Superheater-Tubing Materials in Contact with Combustion Atmospheres at 730°C. (1350°F.).

Protection of a Mercury Boiler from Corrosive Attack encountered when Burning a Heavy Residual Fuel-Oil.

Resistance of Cast Iron-Nickel-Chromium Alloys to Corrosion in High-Temperature Gas Atmospheres.

Some of the main conclusions drawn from the test records (extensive details of which are recorded in the paper) are given below:—

'Corrosion was most severe when a high sulphur-high vanadium fuel oil, or a high-alkali-content coke and blast furnace gas was burned. At a furnace temperature of 730°C. (1350°F.), under severe corrosive conditions, the best general performance of the alloys tested was obtained with a high-nitrogen-containing 24 per cent. chromium, 14 per cent. nickel-type alloy and with the 25 per cent. chromium- 20 per cent. nickel-type alloys containing either normal or high (2·20 per cent.) silicon.

'A second research project involved the determination of means for protecting a mercury boiler from severe tube corrosion resulting when a high sulphur-high vanadium fuel oil was burned. Various procedures were studied in a laboratory-scale boiler furnace, and at present it appears that a metallized coating of a 26 per cent. chromium-balance iron alloy has shown the best resistance to corrosive attack at temperatures up to 815°C. (1500°F.). Test sections in the commercial unit suggest good adherence of the coating to the boiler tubes. The addition of 'calcium tallate' to the fuel oil also reduces corrosion of the boiler tubes.

'Another investigation, conducted for the Alloy Casting Institute over a period of many years, has been concerned with the resistance of cast heat-resistant alloys to corrosion by oxidizing and reducing flue gases at temperatures up to 1090°C. (2000°F.). Sulphur contents of the atmospheres were varied from 0·115 to 11·5 gram/cubic metre. Alloys containing from 0 to 36 per cent. chromium and 0 to 70 per cent. nickel, in combination with iron, were tested. In general, increases in chromium were more effective in reducing corrosion than increases in nickel content. At higher sulphur concentration, the higher-nickel alloys were unsatisfactory. In general, corrosion was more severe under reducing than under oxidizing conditions.'

High-Temperature Mechanical Properties of Intermetallic Compounds

R. LOWRIE: 'Mechanical Properties of Intermetallic Compounds at Elevated Temperatures.'
Jnl. of Metals, 1952, vol. 4, Oct. ; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 1093-1100: T.P. 3386E.

Nine intermetallic compounds were tested in tension at various temperatures: these include nickel-silicon compounds (Ni_3Si, $Ni_3Si+Ni_5Si_2$, Ni_5Si_2 and Ni_2Si). The tensile testing was done in a special furnace designed to permit maintenance of a neutral atmosphere. It is described and illustrated, and a drawing of the test apparatus is shown.

An attempt is made to correlate tensile strength and elongation with melting (decomposition) temperature, valence electron configurations of the component elements, heat of formation, crystal structure, density, and volume decrease accompanying formation of the compounds.

Timken 16-25-6: Production and Properties

M. FLEISCHMANN: 'Hot-Cold Work Improves 16-25-6 Properties.' *Iron Age*, 1952, vol. 170, Nov. 20, pp. 123-7.

The author describes treatment and properties of the alloy developed by Timken Roller Bearing Company in 1942, and widely used in the U.S.A. during the war

Table I

C %	Mn %	P %	S %	Si %	Cr %	Ni %	Mo %	N %
0·12 max.	2·0 max.	0·03 max.	0·03 max.	1·0 max.	15·0-17·5	24·0-27·0	5·5-7·0	0·10-0·20

for gas-turbine and supercharger applications. The above composition is given as typical.

With a view to extension of use of the alloy in stationary power units, extensive long-time tests have been made. Details are given, *inter alia*, of room-temperature mechanical properties of 16-25-6, (*a*) as solution-quenched from 2150°F. (1175°C.), and (*b*) as hot-cold worked and tempered for 6 hours at 1275°F. (690°C.): see results in table below.

It is seen that hot-cold working treatment (hot-rolling, followed by finish rolling at 1500°F. (815°C.)) considerably enhances the mechanical properties, and creep tests confirmed the beneficial effect of such treatment. Tests at 1200° and 1300°F. (650° and 705°C.), of at least 10,000 hours' duration, were conducted, in both conditions: two stresses were used at each temperature, on material in each condition of treatment. A third stress, of 20,000 p.s.i. (9·0 tons per sq. in.), extending over nearly two years, was also made on the solution-treated alloy at 1200°F. (650°C.). Curves in the paper give full results. Comparison of the behaviour of the solution-treated and the hot-cold worked and tempered material showed that at 1200°F. (650°C.) total deformation, as well as creep rate, of the solution-treated alloy is many times that of the hot-cold worked specimen, especially after long time of test. At 1300°F. (705°C.) practically identical creep rates were observed for the alloy in the two conditions between 2,000 and 6,000 hours, although total deformation of the solution-treated alloy was about twice that of the hot-cold worked alloy under the same stress. The curves indicate that, at least up to a temperature of 1300°F. (705°C.), total deformation under a given stress may be materially reduced by previous 'cold working' of the alloy. In stress-rupture tests on the solution-quenched alloy at 1000°-1500°F. (540°-815°C.), and on the hot-cold worked alloy at 1200°, 1300° and 1400°F. (650°, 705° and 760°C.), some of the stresses used resulted in rupture times exceeding 10,000 hours. At the lower temperatures in the test range used the hot-cold worked material proved stronger than the solution-quenched alloy, but this superiority was not retained at 1400°F. (760°C.). Elongation-to-fracture data indicate that ductility decreases as rupture time is extended.

An outstanding development in connexion with design of jet engines has been the composite turbine wheel, in which a high-alloy rim is welded to a hub of low-alloy material. The 16-25-6 alloy has been successfully used for the rim, welded to a hub of S.A.E. 4340 nickel-chromium-molybdenum steel. A new method of cold expanding turbine wheel rims (subject of patent application by Timken) will facilitate the hot-cold working which is necessary to produce optimum properties in the rims. The salient features of the new method are outlined in this article.

Elevated-Temperature Embrittlement in Austenitic Chromium-Nickel Steels

G. HOCH: 'Elevated-Temperature Embrittlement in Austenitic Chromium-Nickel Steels.'
Archiv f.d. Eisenhüttenwesen, 1952, vol. 23, July-Aug., pp. 257-75; disc., pp. 275-6.

This report contains a very large amount of experimental data, on a range of steels containing chromium 12-27 per cent., nickel 8-20 per cent., with varying carbon content, including the extra-low-carbon grades,

Table II

Mechanical Properties after Heat-Treatment

Heat-Treatment	Proportional Limit		Yield Strength 0·1%		0·2%		Ultimate Strength		Elongation % in 2 in.	Reduction of Area %	B.H.N.	Grain Size
	p.s.i.	t.s.i.*	p.s.i.	t.s.i.*	p.s.i.	t.s.i.*	p.s.i.	t.s.i.*				
Solution-Quenched 2150°F. (1175°C.)	25,000	11·0	48,500	21·5	51,000	23·0	118,000	52·5	46·0	64·8	188	4–6
Hot-Cold Worked, Tempered 6 hours at 1275°F. (690°C.)	75,000	33·5	117,000	52·5	120,000	53·5	150,000	67·0	18·0	32·0	302–321	8

*To nearest half ton.

steels in which carbon was of the order of 0·1 per cent., and a few in which the carbon was about 0·3 per cent. Provision was also made for study of the influence of stabilizing elements.

In the first part of the investigation the author deals specifically with embrittlement resulting from heating for 1,000 hours (within the range 300°-1,000°C.), as determined by notched-bar impact tests, made both at room temperature and at the temperatures of heating. Bend tests were also made, on sheet material, after exposure. The influence of *time* of heating was studied, using an annealing temperature of 800°C. In the second part of the paper a report is made of tensile tests at elevated temperatures, as a means of studying embrittlement.

In the impact-test series it was found that the steels grouped themselves, according to certain outstanding characteristics, into four groups, the individual behaviour of which is discussed in relation to composition and structure. A steel representative of each of these groups was included in the series used for hot-tensile testing. A total of 93 steels were studied in the two parts of the research: much detailed information is given in the report, and critically analyzed.

It is concluded that the embrittlement revealed by notched-impact and bend testing after prolonged heating in the region 600°-900°C. is clearly attributable to precipitations of carbide, martensite, or the intermetallic compound FeCr. Results of tests at the temperatures of exposure, taken in association with those made at room temperature after prolonged heating, show that carbide embrittlement and the embrittling effect of FeCr are practically as potent at the elevated temperatures as after cooling. Martensite embrittlement, however, resulting from holding the steels above the change point and subsequent cooling, is obviously apparent only at room temperature. Data from the notched-impact tests were confirmed by thermomagnetic measurements, measurements of magnetic saturation, Brinell hardness determinations, and investigation of structure.

The experiments recorded did not provide clear proof of the cause of the embrittlement at about 600°-900°C. revealed by hot-tensile tests. It was, however, established that this effect must be essentially different in nature from the brittleness shown by impact tests. (The type of embrittlement observed in the hot-tensile tests was found also in a steel containing about 36 per cent. nickel.) In the chromium-nickel steels investigated by the author it was found that titanium tends to inhibit loss of ductility, but that niobium has not the same effect.

Oxidation Characteristics of Nickel- and Cobalt-base Alloys at High Temperatures

A. PREECE and G. LUCAS: 'The High-Temperature Oxidation of Some Cobalt-base and Nickel-base Alloys.' *Jnl. Inst. Metals*, 1952-53, vol. 81, Dec., pp. 219-27.

The results reported in this paper were obtained during a general survey of the high-temperature oxidation of binary alloys based on cobalt and on nickel, and a more detailed examination of a cobalt-chromium alloy containing additions of third elements. The binary range covered was:—

Cobalt +10, 20, 25, 32 and 40% Cr
+5, 10 and 15% W
+5, 10 and 15% Mo
+5% Al
+40%Ni

Nickel +5, 10 and 15% W
+5, 10 and 15% Mo
+5% Al

Nickel-chromium alloys were omitted, in view of the large amount of research already carried out on this series. The cobalt-tungsten, nickel-tungsten and nickel-molybdenum alloys were prepared by powder-metallurgy techniques, details of which are given; the remainder of the alloys were vacuum melted, and specimens for test were cut from the ingots without further treatment.

The apparatus devised for oxidizing the specimens was designed to simulate a gas-turbine atmosphere. Paraffin was used as the fuel, and was allowed to flow into a controlled stream of air supplied from a small compressor. The mixture was burned in the combustion furnace, maintained at 950°C., before being led to the furnaces containing the specimens. Full details are given of the equipment, with drawing. The composition, by volume, of the atmosphere in the test furnaces was carbon monoxide 3·5, water 3·3, sulphur dioxide 0·06, per cent., the remainder being air slightly enriched in nitrogen. The rate of flow of this atmosphere over the specimens was well above critical speed, and the furnaces were arranged to operate over the range 800°-1200°C. It was found that oxidation results in the atmosphere described showed no appreciable difference from those obtained in air.

Results for each series of specimens are reported, in tables and curves. Some of the main observations on the nickel-containing materials are summarized below:—

Nickel: Rates of oxidation of nickel (and of cobalt) were examined in oxygen as well as in the synthetic gas-turbine atmosphere.

A scale consisting of two separable layers of identical composition observed in the oxidation of nickel comprised a dark-green, coherent, outer layer and a light-green, powdery, inner layer, both NiO. If nickel oxide is heated alone it absorbs extra oxygen and acquires a dark-green colour comparable with that of the outer scale layer. Two separable layers of similar nature were also observed on cobalt, and in both cases the dividing line between the two layers coincided with the original metal surface. DUNN's observation that oxidation of nickel proceeds preferentially along the grain boundaries was confirmed in the present experiments.

Cobalt-Nickel Alloys: With additions of up to 40 per cent. of nickel the rate of oxidation of cobalt decreased almost linearly. The scales formed were adherent, and in external appearance resembled those

formed on cobalt. No sign of internal oxidation was found below 1000°C., and only a small amount was observed at the higher temperatures. Both layers of the scale formed consisted of a solid solution of nickel oxide in cobalt oxide; the amount of nickel oxide present in the inner layer was greater than that in the outer one.

Nickel-Molybdenum Alloys: Addition of up to 15 per cent. of molybdenum had little effect on the rate of oxidation of nickel at 800°-900°C., but at higher temperatures 5 per cent. of molybdenum caused a slight increase. Additions beyond 5 per cent. did not, however, sustain this initial rise. At 1200° a maximum was attained at approximately 10 per cent. molybdenum. No volatilization of MoO_3 was observed in these alloys.

Scales formed at all temperatures consisted of two layers: a dark-green, coherent, outer layer of NiO and a bright-green, powdery, inner layer which was a mixture of NiO and nickel molybdate, $NiOMoO_4$. On cooling, the outer layer broke off, as a result of disintegration of the nickel molybdate. A similar effect was observed in cobalt-molybdenum alloys. A small amount of internal oxidation was observed in nickel-molybdenum alloys at the higher temperatures used.

Nickel-Tungsten Alloys: The presence of up to 15 per cent. of tungsten in nickel effected little change in rate of oxidation at temperatures below 1000°C., but at 1100° and 1200°C. it caused a moderate increase. The oxide layers formed on the nickel-tungsten alloys were similar in appearance to those formed on nickel, and were adherent at all test temperatures. The outer layer consisted mainly of NiO, with traces of nickel tungstate, $NiWO_4$: the inner layer of nickel tungstate with some NiO. Internal oxidation occurred to a considerable extent over the range 900°-1200°C.: its severity was a function of temperature and amount of tungsten present.

Nickel-Aluminium Alloys: Results in this series were unusual, in that a maximum was observed in the oxidation curve at 1100°C. At 800°C. the alloys were very resistant to oxidation, due to formation of a protective film of alumina, but at higher temperatures the protective influence of alumina was lost, and up to 1100°C. the rate of oxidation was greater than that for nickel. Beyond 1100°C. the presence of aluminium again became effective and the rate of oxidation was appreciably lower than that of nickel. The scales formed at 900° and 1000°C. were duplex in character, consisting of NiO with some alumina in the inner layer. Internal oxidation began at 900° and became more intense at 1000°C. At temperatures between 1100° and 1300°C., however, there was no internal oxidation, and the layers of scale consisted of (*a*) an outer one of NiO, (*b*) a thin, powdery layer of nickel aluminate and NiO, and (*c*) a greyish layer of alumina on the surface of the alloy. On cooling, layers (*b*) and (*c*) spalled off. As the temperature rose the volume of nickel oxide, and also the amount of spinel, decreased, while the film of alumina provided more complete coverage. Experiments with mixtures of nickel oxide and aluminium oxide confirmed that no formation of spinel occurred until the mixture was heated above 1000°C.

In this series, 5 per cent. of aluminium appears to be sufficient to prevent oxidation of the base metal, except at 800°C. Attention is directed to the change in mechanism of oxidation taking place at about 1050°C. Rate of diffusion of aluminium through nickel, with subsequent formation of aluminium oxide at the surface of the alloy, is favourably influenced by rise of temperature, and it is considered probable that at the higher temperatures the rapid formation of a surface layer of aluminium oxide restricts further oxidation of nickel.

Extrusion of High-Alloy Materials by the Ugine-Séjournet Process

'American Application of the Ugine-Séjournet Extrusion Process.' *Engineer*, 1952, vol. 194, Nov. 21, pp. 680-3: see also *Blast Furnace and Steel Plant*, 1952, vol. 40, Oct., pp. 1184-9.

This article outlines the history of the process and describes its application in the U.S.A., with particular reference to the installation in the works of the Tubular Products Division of the Babcock and Wilcox Company, Beaver Falls, Pennsylvania. See also earlier reference to the basic features of this process in *Nickel Bulletin*, 1952, vol. 25, Nos. 8-9, p. 219.

Resistance of Nickel-containing Alloys to Salt-Bath Media

J. H. JACKSON: 'Cast Alloys for Salt-Bath Heat-Treating.' *Alloy Casting Bull.*, 1952, No. 16, Nov., pp. 1-5, 7-10.

A report is made of research carried out under the aegis of the Alloy Casting Institute. The laboratory stage of the work involved determination of the resistance of 80 alloys of different compositions, to attack by various salt-bath media operating at 1600°F. (870°C.). Most of the alloys tested were of iron-nickel-chromium base, but a sample of mild steel was also included. Alloys of commercial composition were examined, in comparison with several special alloys in which the carbon was reduced to a particularly low level and to which carbide-stabilizing additions had been made. The effects of silicon and of aluminium additions were also specifically studied.

The tests were conducted in a special alloy container which was electrically heated; details of the test apparatus are illustrated. Five types of salt bath were used, as representative of those employed in high-temperature work, namely,

(1) 50% NaCl—50% KCl.
(2) 50% Na_2CO_3—50% KCl.
(3) 20% NaCl—25% KCl—55% $BaCl_2$.
(4) 25% NaCl—75% $BaCl_2$.
(5) 21% NaCl—31% $BaCl_2$—48% $CaCl_2$.

The experiments covered study of—

effect of bath oxidation and the addition of rectifiers;

effect of operating variables (sodium fluoride

additions, formation of sludge, intermittent immersion, and partial immersion);
influence of type of salt;
effect of grain size of the cast alloys;
effect of pre-treatment by cyaniding;
effect of cyanide additions to the salt baths.

From the results presented, it is concluded that the corrosion-resistance of heat-resisting alloys currently available can be usefully increased (to the extent of raising pot life 1½-5 times) by relatively simple modifications of present practice. For example, resistance of the HT (35-15 nickel-chromium-iron) alloy and the HW (60-12 nickel-chromium-iron) type can be increased by reducing the carbon content from the 0·45-0·50 per cent. generally found, to about 0·08 per cent. In some environments a 17 per cent. chromium alloy containing little or no nickel gives particularly satisfactory service.

Most of the variable factors involved in use of alloys in salt-bath operation do not seriously affect rate of corrosion attack, due mainly to the fact that the alloys eventually fail by intergranular penetration of corrosion, not by solution or outright loss of metal. For example, variations in type of salt-bath rectifier used, exposure to alternate immersion, and addition of sodium fluoride to the bath, increased corrosion by less than 25 per cent. Collection of sludge in the bottom of the pot appears to be harmful, since (*a*) at constant temperature it increased the rate of attack by about 25 per cent. for many alloys and in some cases doubled the corrosion rate, and (*b*) in commercial operation it would tend to increase pot temperatures, thus resulting in increased corrosion.

It was observed that, under laboratory conditions, additions of about one per cent. of sodium cyanide every 12 hours resulted in marked reduction in corrosion of the alloys studied. Attempts to adapt this finding in production have, however, resulted in a change in the nature of the bath, and decarburization of the work occurs. It will be necessary to find a means of combatting the decarburizing influence of the sodium cyanide addition, in order to utilize this means of prolonging life of the alloys under normal salt-bath working conditions.

Corrosive Attack as a Factor in Design and Lubrication

'Corrosion Factors in Design and Lubrication.'
Product Engineering, 1952, vol. 23, Oct., pp. 142-7.

In this article (based on material supplied by F. L. LAQUE and associates of the International Nickel Company) it is pointed out that corrosive attack on metallic materials is a function of many variables, not merely of the composition of the material and the nature of the corroding medium. Two major influences determining resistance to corrosion in service are design and lubrication: these variables must be carefully studied if maximum durability is to be obtained from any given material. Improper design can be a seriously accelerating and intensifying influence, by setting up electrolytic action, which can be initiated by the presence of crevices, critical velocities and turbulence of corrosive fluids, galvanic couples, and contact of active and passive surfaces. Each of these conditions is discussed in this article, and some suggestions are made with regard to prevention of corrosion due to unsuitable design. Typical examples of attack induced or intensified by bad design or service conditions are illustrated.

In the second section of the article attention is drawn to corrosion which may arise from attack by chemical changes occurring in lubricants used with bearings, in automobile cylinders, and in other engineering components. Some recommendations are made on measures which may be used to prevent such attack.

The final section contains notes on fretting corrosion, a form of deterioration which occurs on closely fitting parts subject to vibration or other conditions giving rise to infinitesimal slip between surfaces. Tests made at the N.A.C.A. laboratory, Cleveland, Ohio, have shown that molybdenum disulphide is superior to all other lubricants yet studied, in prevention of this form of corrosion.

Influence of Operating Conditions on Resistance to Corrosion

E. A. TICE: 'Preserving What You Have from the Corrosion Engineer's Standpoint.'
Chemical Engineering Progress, 1952, vol. 48, July, pp. 329-32.

This article is also of general interest in relation to operation of chemical-engineering plant. The author discusses three factors affecting the resistance of metallic materials to corrosion:—*aeration*, or the presence of oxidizing agents; *velocity of flow* of corroding media, or agitation effects; *temperature*. The influence of each of these variables is considered by reference to typical cases in which it modifies the resistance of a specific material to attack. *Aeration* is discussed in relation to the behaviour, in sulphuric acid, of Monel (in which case oxidizing agents must be kept to a minimum) and stainless steel (which depends, for its resistance, on formation of an oxide film, and for which oxidizing conditions are therefore beneficial). *Velocity* effects, and the different ways in which these may operate, are demonstrated by reference to performance of Monel in dilute sulphuric acid, variation of resistance of various condenser-tube materials in sea water of given velocity, and behaviour of stainless steel in sea water. The general tendency towards increase in corrosion with rise in *temperature* is illustrated by data on attack of nickel and Monel in hydrochloric acid, and the influence of rising temperature on solubility of oxygen and of the corrosion product is considered, as affecting corrosion rates of Monel and of stainless steel under specified conditions. Finally, attention is directed to the changes which may be effected in the nature of the corrosion-product film by rise in temperature, transforming a film which is protective at normal temperature into a non-protective one.

Typical cases of service operation are briefly outlined, to indicate simple changes which may be made in chemical equipment to overcome some adverse effects of temperature.

Corrosion by Water: Effects of Velocity

H. R. COPSON: 'Effects of Velocity on Corrosion by Water.' Reprint from *Industrial and Engineering Chemistry*, 1952, vol. 44, Aug., pp. 1745-52. Issued by International Nickel Co., Inc.

This paper was presented at the Symposium on Water Corrosion, organized by the American Chemical Society: see *Nickel Bulletin*, 1952, vol. 25, No. 10, p. 247. It includes data on resistance of cupro-nickel to sea water, as influenced by velocity, also results of cavitation - erosion tests on nickel - containing materials.

Corrosion Charts: Comments on Mode of Presentation

'Corrosion Charts Analyzed.' *Chemical Engineering*, 1952, vol. 59, Sept., pp. 264, 266-8, 270-2.

Comments on series of charts recently issued by this journal; for details of some of these see *Nickel Bulletin*, 1952, vol. 25, Nos. 10 and 11, pp. 243 and 274. While general appreciation of the form of the charts is expressed, several writers emphasize their limitations as a source of reliable reference data.

Corrosion Inhibitors: Reference List

M. BROOKE: 'Corrosion Inhibitor Checklist.' *Chemical Engineering*, 1952, vol. 59, Sept., pp. 286-7.

This list is compiled for the use of chemical engineers confronted with the problem of processing a liquid in a vessel not primarily designed to handle it, but capable of being made more serviceable by the addition of inhibitors to the substances being processed. The information given is based on a survey of the literature, to which references are given. The list shows metallic materials (aluminium, copper and brass, magnesium, Monel, stainless steel, steel, tinplate), environment, and inhibitors which may be used.

Influence of Carbon Content on Acid-Resistance of Nickel-Chromium Steels

H. T. SHIRLEY and J. E. TRUMAN: 'The Influence of Carbon Content on the Acid Resistance of Titanium- and Niobium-Stabilized 18 Cr, 8-14 Ni Steels.' *Jnl. Iron and Steel Inst.*, 1952, vol. 172, Dec., pp. 377-80.

The importance of carbon content in relation to intercrystalline corrosion of 18-8 chromium-nickel and related steels is well appreciated, and the boundary precipitation of chromium carbides is now generally accepted as the cause of this deterioration. Addition of titanium or niobium as stabilizing agents (in amounts depending on the carbon content) has been found to give virtual immunity from this type of corrosion, for most practical purposes, in steels containing carbon up to about the normal maximum of 0·15 per cent. It has, however, been suggested that the carbon content of titanium-stabilized steels should preferably be below 0·08 per cent., such recommendation being supported by data indicating the relative corrosion-resistance, in boiling 65 per cent. nitric acid, of titanium-stabilized steels containing, respectively, 0·09 per cent. carbon with 0·58 per cent. titanium, and 0·15 per cent. carbon with 0·76 per cent. titanium.

In an earlier paper one of the present authors pointed out the extremely searching nature of this type of nitric-acid test, in respect of even a slight tendency to intergranular failure, particularly at delta boundaries. His argument has since been further supported by data showing that the influence of carbon content is much less potent with regard to resistance of a given steel (in the sensitized condition) to attack by sulphuric, hydrochloric or acetic acid solutions, than in boiling nitric acid.

The present paper contains data amplifying these earlier observations, and describes tests covering steels of a wider range of carbon content (0·03 to 0·16 per cent.), stabilized with (*a*) titanium or (*b*) niobium. In many cases determinations of loss in weight were supplemented by study of the microstructural characteristics of the corroded steels. Fifteen materials were studied, within the limits of composition indicated above, being tested in the form of 2-in. × ½-in. samples from ⅛-in. hot-rolled sheet. The samples were sheared, and treated for 10 minutes at 1050°C., followed by air cooling or water quenching. Certain samples were then subjected to treatment at 650°-850°C.: full details of the treatments are given. Microstructure revealed no delta constituent in 18-13 niobium-stabilized steel: in four other steels, of the 18-8 type, a small amount of delta was found. All the samples were finally emery finished to 120 grade.

Tests in 65 per cent. boiling nitric acid were made in 250 ml. of solution, changed at the end of each 48-hour period. Conditions of other tests, in (1) boiling 30 per cent. acetic acid, (2) 0·5 and 2·5 per cent. hydrochloric acid at room temperature, and (3) 10 per cent. sulphuric acid, at room temperature, were selected to cover those of slight-to-moderate attack, just beyond the region of uncertain passivity breakdown. All steels were subjected also to the standard copper sulphate-sulphuric acid test.

Results are tabulated, and typical photomicrographs illustrate the structural conditions of the steels after exposure to boiling nitric acid. They show that, given satisfactory stabilization against intercrystalline corrosion, as judged by the standard $H_2SO_4/CuSO_4$ test, the effect of carbon content was small. No effect was found in the acetic- and hydrochloric-acid tests. In the 10 per cent. sulphuric-acid solution the effect was limited to a doubling of the attack as the carbon content increased from 0·04 to 0·10 per cent. This occurred with both types of stabilization, and was independent of heat-treatment.

In the nitric-acid test, treatment of the niobium-stabilized steels for ½ hour at 650°C. or 5 min. at 700°C. produced an increase of two to three times in the amount of attack, but there was no difference attributable to carbon level within the series. With these treatments, the titanium-stabilized steels showed a rather greater rise in attack (up to four or five times) at the highest carbon level. In imperfectly stabilized steels which showed susceptibility to intercrystalline corrosion in the $H_2SO_4/CuSO_4$ solution, nitric acid was the only other reagent revealing any effect from heat-treatment at 650° or 700°C.

Influence of Rate of Drawing on the Magnetic Properties of Austenitic Steel Wire

S. STORCHHEIM: 'How Draw Speed Affects Stainless Wire.' *Amer. Machinist*, 1952, vol. 96, July 21, pp. 124-5.

In the plant of Wilbur B. Driver Company it was observed that, even under standard conditions of drawing, considerable variation was found in the magnetic properties of nickel-chromium austenitic steel wire. Following preliminary investigation, which indicated that the differences resulted from variations in the speed at which the wire was drawn, a systematic study was made of the influence of drawing speed on the magnetic properties of wire of two typical austenitic steels, of compositions shown in Table I.

The following details are given:—

The wires, initially 0·016 in. diameter, were annealed at 2100°F. (1150°C.) and were drawn through 13 successively smaller B. and S. gauge dies, to 0·004 in. diameter: reduction 93·7 per cent. Table II shows the influence of rate of drawing.

The following comments are made: 'Property fluctuations are probably caused by the generation of heat in the wire during the draw. Higher speeds through the die mean more frictional heat, and greater wire speed reduces the time for heat dissipation from the wire before it is drawn through another die. This higher temperature probably retarded the austenite-to-martensite transformation, as it is recognized that when the temperature of 18-8 stainless steel rises much above room temperature during cold deformation, this transformation is inhibited. This condition is probably the cause of lower ferromagnetism, tensile strength, and resistivity.'

Table I

Type	C %	Mn %	P %	S %	Si %	Mo %	Ni %	Cr %
302	0·08	0·91	—	—	0·59	0·08	9·41	18·39
304	0·07	1·07	0·030	0·018	0·40	0·19	8·47	18·91

Table II

Steel	Rate of Reduction f.p.m.	H_c Oersted	B_r Gauss	U.T.S.		Resistivity ohm-cm / ft.
				p.s.i.	t.s.i.	
302						
1	50	70	7850	395,000	176·5	555
2	100	90	7700	325,000	145·0	540
3	200	160	5450	372,000	166·0	500
4	300	170	5180	369,000	165·0	500
5	400	160	5180	372,000	166·0	500
6	1000	170	4000	372,000	166·0	490
7	1500	160	3850	369,000	165·0	500
8	2000	155	4250	356,000	159·0	510
9	2500	160	4000	365,000	163·0	500
10	3000	160	4250	372,000	166·0	490
11	3900	170	4000	372,000	166·0	485
304						
1	45	35	5330	372,000	166·0	615
2	130	40	6400	357,000	159·5	610
3	235	55	7200	361,000	161·0	600
4	315	55	6930	361,000	161·0	595
5	395	80	7070	357,000	159·5	585
6	510	70	7330	357,000	159·5	590
7	1000	80	6670	357,000	159·5	580
8	1500	80	6400	357,000	159·5	570
9	2000	85	6000	350,000	156·0	560
10	2500	80	6000	357,000	159·5	560
11	3000	90	5460	357,000	159·5	555
12	3900	85	5460	357,000	159·5	555

Stainless Steel for Non-Magnetic Applications

F. K. BLOOM and J. S. WHITE: 'Selection and Processing of Chromium-Nickel Stainless Steel for Magnetic Applications.' *Wire and Wire Products*, 1952, vol. 27, Oct., pp. 1036-8, 1126-7.

The use of nickel-chromium stainless-steel wire is of growing importance in parts for which high strength and non-magnetic properties are required, in addition to corrosion-resistance. Typical examples are ignition conductor wire in aircraft, armature binding wire, and braid wire used in the sheath of military field carrier cable. Experience in processing this type of material has shown that its magnetic properties are affected to an important extent by composition, drawing practice, and other variables. The present article gives a review of current knowledge on this subject.

Chromium-nickel steels of the austenitic grades are relatively soft in the annealed condition, and have normally a magnetic permeability of about 1·005 (air = 1·00). This permeability does not vary appreciably over field strengths of 10-200 oersted. On cold working these steels strengthen and work-harden rapidly, and some are apt, in the cold-worked condition, to become magnetic. This feature is a disadvantage in such items as cold-headed panel screws for instruments, whereas in other applications, such as magnetic-recording wire, permeability is desirable, in combination with high tensile strength. Correct selection of the grade of steel to be used for a particular application therefore depends on a knowledge of change in magnetic properties as a function of composition and cold work. As regards the first of these variables, chromium, nickel and carbon have the most determining influence on the rate at which the steels become magnetic on cold working. Manganese and other elements have a less important influence. In general, steels having the lowest chromium and nickel contents become magnetic most rapidly under cold work, and also increase in tensile strength at the highest rate.

Various grades of austenitic steel are specifically discussed in this article: some typical data are shown in Table I below.

An associated figure demonstrates the properties of Types 301, 302, 304, 316 and 310, showing that the mechanical strength values attained by cold working are in that (descending) order.

Composition also materially affects the coercivity and residual induction of cold-drawn chromium-nickel steel wire. These properties are of importance in magnetic-recording wire, and must be held within comparatively narrow limits for satisfactory performance. It is customary to draw such wire through very heavy reductions (over 90 per cent.), and in the course of such processing steels normally considered non-magnetic may change to such an extent as to become strong permanent magnets. Table II illustrates the

Table II
Effect of Cold Reduction on Magnetic Residual Induction and Coercive Force

% Cold Reduction	Type 302 C 0·05, Mn 0·63, Cr 18·85, Ni 8·80%		Type 304 C 0·05, Mn 0·58, Cr 18·51, Ni 10·59%	
	Residual Induction* Gauss	Coercive Force* Oersted	Residual Induction* Gauss	Coercive Force* Oersted
70	3850	80	100	275
80	4800	60	1000	230
90	5700	45	2200	190
95	6100	40	3000	170

*H = 400 oersted.

effect of varying cold reduction on two 18-8 steels, and Table III on p. 26 shows the influence of drawing speed on a typical 18-8. It is noted in this latter connexion that one heavy pass does not raise the magnetic permeability to the same extent as does the same total reduction effected in several stages.

The authors urge that in view of the number of vari-

Table I
Effect of Cold Reduction on Magnetic Permeability
Annealed Wire 0·298 in. diameter: drawn in single passes at low speeds

AISI Type No.	Composition					Magnetic Permeability*				
							After Cold Drawing			
	C %	Mn %	Cr %	Ni %	Others %	Annealed	10%	20%	40%	70%
301	0·11	1·26	17·15	7·41	—	1·010	1·56	6·64	21·3	40·0
302	0·09	0·48	18·30	8·34	—	1·007	1·18	3·11	12·3	36·8
304	0·06	0·58	18·48	10·18	—	1·004	1·006	1·092	1·36	2·93
316	0·06	1·52	17·32	12·54	Mo 2·30	1·003	1·004	1·004	1·005	1·009
310	0·13	2·09	27·48	21·48	—	1·005	1·004	1·004	1·004	1·007

* H = 100 oersted.

Table III
Effect of Drawing Speed on Residual Induction and Coercive Force

Type 302	Wire drawn from 0·016 in. diameter to 0·004 in. diameter, 93·7% reduction in 13 passes	
	C 0·08 Mn 0·91 Cr 18·39 Ni 9·41 per cent.	
Drawing Speed ft. per min.	Residual Induction* Gauss	Coercive Force* Oersted
50	7850	70
100	7700	90
200	5450	160
400	5180	160
1000	4000	170
2000	4250	155
3000	4250	160

*Magnetizing field strength not given.

ables involved, orders for wire in which magnetic properties are of importance should be given in specific terms, in order to facilitate selection, by the supplier, of the optimum composition and conditions of processing.

Precipitation-Hardening Nickel-Chromium Steels in Aircraft Construction

G. A. FAIRBAIRN: 'Precipitation-Hardening Steels Show Advantages in Aircraft.' *Soc. Automotive Engineers, Preprint No.* 829, Oct., 1952; 8 pp.

This paper reports the experience of North American Aviation, Inc., in the use of three types of precipitation-hardening steel:—

(1) 17-4 PH (chromium 16·5, nickel 3·5, copper 3·5, niobium+tantalum 0·35, per cent.);
(2) 17-7 PH (chromium 17, nickel 7, aluminium 1, per cent.);
(3) Stainless 'W' (chromium 17, nickel 7, aluminium +titanium 1, per cent.).

Essentially, the advantages offered by such materials are the provision of the inherent corrosion-resistance of stainless steel, combined with mechanical strength comparable with that of heat-treated low-alloy steel. Typical properties are quoted for the respective materials, and illustrations are shown of parts for which the steels have been successfully used, e.g. :—

17-4 PH

Introduced mainly as a replacement for Type 416 chromium steel, which had shown inadequate corrosion-resistance and uncertain response to heat-treatment.

Shimmy damper assembly, requiring resistance to marine atmosphere, combined with high strength.

Aeroplane wing hoisting eye assembly, a part subject to rough handling and marine corrosive conditions.

Rocket igniter head, in which the points must be sufficiently hard to prevent brinelling, and which must be capable of resisting corrosion in the rocket exhaust gas, in order to provide good electrical contact with the igniter buttons on the rocket.

17-7 PH

Introduced as replacement for half-hard Type 302 stainless steel, the use of which was placing undue limitations on design, and necessitating the use of excessively heavy forming equipment. 17-7 PH gives equally good resistance to corrosion and can be formed in the 'soft' condition and subsequently hardened, without undue warpage. Details of the heat-treatment and pickling practice used at the North American Aviation plant are given. Items now constructed in 17-7 PH include—

Contoured hat section, which is a side frame in a fuselage structure assembly, for which good forming properties are essential.

Splice angles formed simultaneously on a punch press form die.

Fuselage structure assembly.

17-7 PH is also being used in the form of wire, providing a material comparable in strength to music wire, with the added advantage of resistance to corrosion. A typical application of the wire is in safety pins used in a canopy ejection mechanism for pilot emergency bale-out. In service this pin must be pulled out of the ejection mechanism while under heavy side loads from a spring-loaded firing plunger. Essential properties are, therefore, sufficient strength to resist plastic bending, coupled with hardness sufficiently high to obviate scoring, which would prevent its being removed from the firing mechanism.

Stainless 'W'. This steel also replaces Type 302 half-hard sheet, and in production of a fuselage frame structure (formed on a punch press form die) it has been established that five times as many acceptable parts can be made when using Stainless 'W' as when using the 302 steel, with expenditure of the same number of manhours.

Stainless Steels used in Sweden

G. LINDH and H. NATHORST: 'Corrosion-Resisting Steel. Review of Types Produced in Sweden.' *Jernkontorets Annaler*, 1952, vol. 136, No. 10, pp. 413-28.

Composition, properties and principal uses are described. Both standardized and non-standardized types are included, and the designations of steels commercially produced by Swedish steelworks in the various grades are recorded.

Welding and Flame Cutting of Stainless Steels

H. THIELSCH: 'Welding Processes and Procedures Employed in Joining Stainless Steels.' *Welding Research Council Bull.* 14, Sept., 1952; 48 pp. Price 2 dollars.

The report is issued under the aegis of the Literature Advisory Committee of the Welding Research Council.

It comprises a well-arranged review of published and unpublished information on metal-arc, carbon-arc, gas, and resistance welding, and oxygen cutting. The information is essentially of a practical, reference character. Its scope is indicated below, by means of a skeleton list of contents:—

Introduction (general notes on welding characteristics of the stainless steels and procedures used).

Metal-Arc Welding (Shielded-metal-arc, submerged-arc, atomic-hydrogen, inert-gas metal-arc, inert-gas shielded-arc processes).

Carbon-Arc Welding (Carbo-Flux process).

Gas Welding (Oxy-acetylene, stitch-flame, pressure-gas processes).

Resistance Welding (General notes; spot, multiple-impulse, stitch, push, projection, seam, and flash welding).

Flame Cutting (Oxygen cutting, Oxyarc process, hydrogen-fluorine torch, powder-cutting processes, scarfing processes).

The review is supported by a *bibliography* of 242 items. Some suggestions are made with regard to aspects of the subject requiring further investigation.

See also—

Gas Cutting of Stainless Steel

'Better Cutting on Stainless Steels.'
Welding Engineer, 1952, vol. 37, Oct., pp. 64-6.

This article gives an outline of the characteristics of iron-rich powder cutting, chemical-flux cutting, and arc-cutting methods developed for stainless steels. Tables show conditions for cutting steel of varying thicknesses, by all three methods.

Cupro-Nickel Alloys containing Iron

E. W. PALMER and F. H. WILSON: 'Constitution and Properties of Some Iron-bearing Cupro-Nickels.' *Jnl. of Metals*, 1952, vol. 4, Nov., *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 1216-1217: contained in T.P. 3393E.

Discussion of paper published *ibid.*, pp. 55-64: see *Nickel Bulletin*, 1952, vol. 25, No. 3, p. 63.

In discussion G. L. BAILEY reported that the authors' data on variation in solubility of iron in both 5 and 10 per cent. nickel-copper alloys with temperature were generally in line with conclusions reached in the investigations made by the British Non-Ferrous Metals Research Association, reported in his 1951 paper (see *Jnl. Inst. Metals*, vol. 79, pp. 243-292: *Nickel Bulletin*, 1951, vol. 24, No. 8, p. 185). He raised a query regarding the explanation advanced by the authors of precipitation of the iron-rich phase in the cupro-nickels, and expressed divergence from their views on the optimum iron content for these alloys.

In connexion with their use for applications involving coppersmithing operations, he mentioned development of intercrystalline weakness resulting from grain-boundary separation of α', which is revealed by severe working of material in a susceptible condition.

With regard to the optimum iron content, the authors consider that the variation in conclusions arrived at in the two investigations resulted primarily from differences in condenser-tube practice in U.K. and U.S.A. Further experience, since their paper was published, has led them to agree that the iron content should be limited to the amount which can be retained in solid solution during normal condenser-tube fabrication.

Regarding the intercrystalline weakness, they could report no direct experience of this phenomenon, but suggested that in view of the known susceptibility of some precipitation-hardening alloys to become fragile in the range of temperature in which precipitation can occur, it would not be surprising if alloys of high iron content, with substantial amounts of iron in solid solution, were to develop intergranular ruptures at some critical rate of strain during coppersmithing operations. Such failures would, in their opinion, be less likely with lower iron contents, which would possibly be another reason why alloys of moderate iron content may prove to be more practically useful than those in which a maximum iron content has been used to obtain a relatively slight increase in corrosion-resistance.

Copper-Nickel-Silicon Alloy Resistant to Stress-Corrosion

C. H. HANNON: 'New Copper Alloy has High Stress-Corrosion Resistance.' *Iron Age*, 1952, vol. 170, Nov. 20, pp. 131-3.

The article describes an alloy developed by General Electric Company, in association with Revere Copper and Brass, Inc. The composition range is given as nickel 3·5-5, silicon 0·7-2, iron 0·3-1, per cent., balance copper. This composition is the result of detailed investigation of the influence of variation in the nickel : silicon ratio, and the iron content is of importance as eliminating susceptibility to stress-corrosion. The alloys within this range have been designated 'Strenicor'. Excellent properties may be developed in either sand-cast or hot-forged parts; the optimum treatment is a solution heating, at 900°C., followed by quenching or rapid cooling, and subsequent ageing at 540°C., for about 2 hours. Typical values so obtainable are shown below:—

The alloy is already in use in transformer terminal clamps, and a further proved application is a sand-cast Belleville-type washer, which is described.

Condition	U.T.S.		Yield Strength*		Reduction of Area %	Elongation in 2 in. %
	p.s.i.	t.s.i.	p.s.i.	t.s.i.		
Sand Cast, Heat-Treated	90,000	40·2	70,000	31·25	8	1
Hot Forged, Heat-Treated	107,000	47·8	83,000	37·0	7	5

* Based on 0·5 per cent. elongation under load.

Welding of Nickel-containing Steels

See abstract on p. 16.

Nickel Plating of Stainless Steel Prior to Brazing

See abstract on p. 9.

X-Ray Fluorescent Analysis of High-Alloy Steels

E. GILLAM and H. T. HEAL: 'Some Problems in the Analysis of Steels by X-Ray Fluorescence.' *Brit. Jnl. Applied Physics*, 1952, vol. 3, Nov., pp. 353-8.

The use of fluorescent X-rays for non-destructive quantitative analysis, which was first studied by von Hevesey in 1929, has recently acquired renewed interest due to improvements made since that time in the efficiency of X-ray tubes and the means of measuring the intensities of weak radiations. The method consists in placing the specimen in a strong X-ray beam, chosen so that each element in the specimen is excited and emits its own characteristic radiation. The resultant radiation is analyzed by means of an X-ray spectrometer.

This paper reports investigation of the proportion of elements of atomic number higher than 20, in steels, by X-ray fluorescence, using a Geiger-counter spectrometer. The work was done primarily with a view to determining the suitability of the method for use as a rapid means of analysis during steelmaking, particularly in the manufacture of high-alloy steels. The authors describe a monitoring system which compensates for fluctuations in X-ray tube output, and increases accuracy. From measurements on some typical high-alloy chromium-nickel steels, it is concluded that unless a very powerful X-ray tube is used the method gives quick results of high accuracy only when more than about 10 per cent. of the alloying element is present. It is also shown that in some cases standard diagrams would have to be drawn up to allow for 'mutual fluorescence'. An appendix to the paper contains a discussion of the theory of X-ray fluorescent analysis.

Ni-Resist (High-Alloy) Corrosion-Resisting Cast Iron

See abstract on p. 13.

Ni-Resist Valves in Contact with Hydrochloric Acid Vapours

See abstract on p. 13.

Corrosion Tests on Tin-Nickel Alloy and Nickel/Chromium Coatings

See abstract on p. 7.

PATENTS

Production of Coarse Powders from Metal Carbonyls

Metal powder predominantly of particle size greater than 10 microns is made by thermal decomposition of metal carbonyl vapours at a lower rate of throughput than that which results in finer powder. The coarse powder so produced is stated to be characterized by specially high magnetic permeability, and to be suitable for low-frequency mass cores. Examples given include carbonyls of iron, nickel, cobalt, molybdenum and rhenium; also carbonyl halogen compounds of the platinum metals, or carbonyl hydrides.

BADISCHE ANILIN- UND SODA-FABRIK.
Brit. Pat. 679,439.

Preparation of Nickel and Oxide Powders

Finely divided metals or oxides are prepared by decomposing the insoluble oxalates of metals, prepared as follows:—

Oxalic acid is added to an aqueous solution of the metal sulphates containing one or more lower sulphates of a metal of varying valency (e.g., iron, nickel, cobalt), in the presence of an organic reducing agent (preferably formaldehyde), and also enough sulphuric acid to reduce the pH to 3 or below. The operation is carried out at a temperature of 40°-90°C. Oxides are preferably produced by heating the precipitate at 400°-800°C. in an oxygen-containing atmosphere; metals are prepared by reduction in hydrogen containing 0·5-10 per cent. water vapour. Metal powders so prepared are specially suitable for making sintered alloys of high magnetic permeability, e.g., containing nickel 78·5, iron 17·5, molybdenum 4, per cent., and for thin discs of cobalt-iron alloy for telephone diaphragms. Sintered magnetic spinels (mixed zinc, nickel, iron oxides) are also mentioned.

STANDARD TELEPHONES AND CABLES, LTD. (inventor, S. E. MAYER). *Brit. Pat.* 679, 172.

Preparation of Nickel Oxide

Carbonyl nickel is dissolved in mineral acid (e.g., nitric acid), the solution is filtered, and the nickel is precipitated by addition of an organic acid or the ammonium salt of an organic acid (preferably oxalic acid or ammonium oxalate). The precipitate is filtered, washed, dried and ignited to nickel oxide in a current of air or oxygen.

LIGNES TÉLÉGRAPHIQUES ET TÉLÉPHONIQUES.
French Pat. 1,012,946.

Preparation of Nickel Catalysts

The solution of a nickel salt is precipitated with an alkali metal silicate at a temperature above 60°C., and preferably at the boiling point. The atomic ratio nickel:silicon in the starting materials is from 1:1 to 1:3, and the mixture is heated until at least half the precipitate consists of nickel montmorillonite $Ni_3(OH)_2(Si_2O_5)_2$. The precipitate is separated, dried, and reduced in hydrogen or a hydrogen-containing gas, preferably at 500°-700°C.

N.V. BATAAFSCHE PETROLEUM MAATSCHAPPIJ.
Brit. Pat. 678,436.

Preparation of Positive Plates for Nickel Alkaline Accumulators

Accumulator plates comprising a thin sheet of metal (e.g., iron) coated on both sides with sintered layers of powder (e.g., carbonyl nickel) are made as follows:

A suspension of powder in nitrocellulose lacquer is applied to the sheet, which is afterwards heated to 900°C. in a reducing atmosphere. The lacquer is

burnt off and the powder sinters to the sheet. Additional thick coatings of powder are then sintered on in any suitable way. If required, the iron sheet may be electroplated with nickel prior to the powder treatment.

R. A. A. JEANNIN. *French Pat.* 1,000,836.

Active material for alkaline accumulators consists of a mixture of nickel hydroxide and flakes or powder of graphite or other conducting material, the mixture being ground for a short time and then subjected to prolonged rolling, until it all passes through a sieve of 80 mesh to the inch. This very fine material is tamped, in thin layers, into metal tubes having a large number of holes, which are very small in order to prevent leakage of the filler material. These filled tubes form the positive electrode.

STÉ. DES ACCUMULATEURS FIXES ET DE TRACTION (inventor, P. JACQUIER). *French Pat.* 1,007,842.

Recovery of Nickel from Sludge formed in Fluorine Manufacture

The following process is used for recovery of nickel from the sludge formed during manufacture of fluorine by electrolysis of acid anhydrous potassium fluoride electrolytes with nickel anodes:—

Addition of aqueous ammonium hydroxide, preferably after oxidation of the iron, dissolves the nickel and potassium, and precipitates the iron as hydroxide, which is filtered off. Concentration of the nickel and potassium solution precipitates the nickel as a nickel salt containing potassium and fluorine, and evaporation of the mother liquor and sublimation of the ammonium fluoride yields pure potassium fluoride.

M. A. PERKINS and M. COUPER, assignors to UNITED STATES OF AMERICA as represented by U.S. ATOMIC ENERGY COMMISSION. *U.S. Pat.* 2,588,041.

Nickel in Printing Plates

A lithographic printing plate consists of a grease-receptive image sheet of nickel or nickel alloy, coated with a water-receptive non-image portion consisting of a layer of chromium or chromium alloy. The chromium layer is etched away at points at which the plate is to print. Alternatively, a third backing layer of base metal may be used behind the nickel. After printing the first image the remainder of the chromium sheet may be removed, the nickel layer anodically treated to confer affinity for water, and the plate re-used by etching away parts of the nickel layer.

A. FISTAL. *Brit. Pat.* 680,436.

Nickel Sulphate in Silver Contact Materials

Contacts specially suitable for repeated make-and-break applications under conditions of high current and high voltage consist of compressed and sintered silver powders through which are distributed particles of a compressed and sintered mixture of nickel sulphate and cadmium oxide. The nickel sulphate forms up to 3·75 per cent. by weight of the whole mass. A preferred composition is given.

IGRANIC ELECTRIC CO., LTD. *Brit. Pat.* 683,343.

Production of Hard, Ductile, Electrodeposits of Nickel

Thick, ductile, and very hard electrodeposits are produced from a bath containing nickel sulphate, nickel chloride, boric acid, and an anti-pitting agent; also 0·5-5·0 g./L. of at least one of the following agents, added to increase ductility: sulphonated or polysulphonated derivatives of naphthalene or aminotoluene, benzone sulphonamide, saccharin. The pH is less than 5 (preferably 2-3). The bath is operated at a temperature above 35°C., with a cathode current density of 6-8 amp./dm².

BOZEL-MALETRA. *Brit. Pat.* 682,173.

Ductile Nickel+Chromium Coatings

A ductile composite coating is obtained by first depositing a ductile but dull nickel layer, followed by a bright nickel layer, removing most of the bright nickel by electrobuffing, and finally chromium plating.

HOUDAILLE-HERSHEY CORPN., assignee of C. N. ISACKSON. *Brit. Pat.* 684,434.

Bright Nickel-Plating Solution

Bright nickel coatings are deposited from a bath containing one or more substances from each of the following groups:—(*a*) sulphonated, unsaturated, and aromatic compounds and their derivatives; (*b*) α-substituted, heterocyclic compounds with nitrogen in the core, in which the substituent is a hydroxyl group, a substituted hydroxyl group, a nitro, or nitroso group. Group (*b*) compounds preferably contain one or more carbonyl and/or carboxylamido groups.

N. V. METALLIC INDUSTRY. *Belgian Pat.* 511,893.

Electrodeposition of Semi-Bright Nickel

Nickel electrodeposits which can readily be buffed are produced from an aqueous electrolyte containing (g./L.) nickel sulphate 120-400, nickel chloride 15-60, formic acid 5-30, boric acid 30-40, coumarin about 1. The pH of the solution is 2·1-2·5. It may also contain up to 0·5 g./L. of formaldehyde, and up to 150 g./L. of magnesium sulphate. Operation is preferably at 60°-80°C. and at a current density of 40-60 amp./sq. ft. Nickel-cobalt deposits may be made from similar baths containing 0·1-3·0 g./L. of cobalt sulphate.

W. CANNING AND CO., LTD., commn. from L. WEISBERG. *Brit. Pat.* 679, 551.

Nickel-Plating of Magnesium and Magnesium Alloys

Magnesium or magnesium-alloy articles to be plated with silver, nickel, cadmium, zinc, or chromium, are cleaned, etched with an acid solution (e.g., hydrochloric or hydrofluoric) free from soluble salts of zinc, cadmium and manganese, and from chlorides of alkali and alkaline-earth metals, then treated with a solution of chromic acid, and finally electroplated.

MAGNESIUM ELEKTRON, LTD. (inventor: W. F. HIGGINS). *Brit. Pat.* 685,219.

Tungsten-base Products Impregnated with Tungsten-Nickel Alloy

Tungsten or tungsten-alloy products of high density, e.g., for balances or X-ray shields, are made by impregnating a sintered or compacted tungsten-base skeleton with a tungsten alloy of eutectic composition, preferably tungsten-nickel.

METRO CUTANIT, LTD. *Brit. Pat.* 679, 994.

Tungsten-Nickel Alloy for Electronic Tubes

The patent covers material suitable for use as the ribbon or filamentary base of oxide-coated cathodes. Powders of a refractory metal, e.g., tungsten, and of a lower-melting-point metal, e.g., nickel, are mixed in the proportions, respectively, of 85-92, and 8-15 per cent., with a binder, to form a paste which is extruded to a continuous tape or filament, and is subsequently sintered. The preferred binder contains nitrocellulose 30, diethyl oxalate 60, dibutylphthalate 10, per cent.

RADIO CORPN. OF AMERICA. *Brit. Pat.* 680,386.

Bismuth-Nickel Alloy

Ductile alloy suitable for extruding to wire is made by adding to chemically pure bismuth 0·1-0·34 per cent. of nickel (preferably 0·16 per cent.). Such wire has the electrical properties characteristic of bismuth.

I. E. ASKE and K. W. FITZPATRICK. *U.S.Pat.* 2,610,913.

Precipitation-Hardening Spring Alloys

Alloys for use in special springs contain nickel 50-68, iron 10-25, chromium 10-25, molybdenum and/or tungsten 5-10, beryllium 0·6-1·2, titanium 0·6-2·0, per cent., with 0-3·0 per cent. of the other usual elements, including manganese and silicon.

R. STRAUMANN. *French Pat.* 1,009, 481.

Nickel-Cobalt-Iron Sealing Alloy

A low-expansion alloy for glass-to-metal seals contains nickel 26·5-29·6, cobalt 17·5, manganese 0·5, copper 0·25-5·0, per cent., balance iron. It has a temperature coefficient of expansion of 20×10^{-7} to 70×10^{-7}. A preferred composition is cited.

J. J. WENT, assignor to N. V. PHILIPS GLOEILAMPENFABRIEKEN. *Canad. Pat.* 486,768.

Thermostatic Bimetals

The low-expansion element of bimetallic strip, etc., is made from an alloy containing cobalt 15-25, nickel 20-35, per cent., balance iron, the nickel+cobalt content being within the range 35-60 per cent. The high-expansion elements may be iron-nickel-manganese, manganese-nickel-copper, pure nickel, or copper. Such bimetals have approximately linear deflection-temperature relationships up to 400°C. Typical examples are given.

STÉ. ANON. COMMENTRY-FOURCHAMBAULT ET DECAZEVILLE (inventors, CHERREAU, GIRARD AND VILLACHON). *French Pat.* 996,105.

Composite Magnetic Material having Good Electrical Conductivity

A homogeneous composite material comprises an alloy having a magnetic saturation of more than 4,000 gauss, compounded with, but not alloyed to, a material having electrical conductivity at least 30 per cent. of that of standard annealed copper. The ferromagnetic material may be a permanent-magnet alloy such as iron - aluminium - nickel, or iron - aluminium - nickel-cobalt, or a nickel-iron alloy of the high-permeability type. Silver or copper is suitable as the high-conductivity material.

METRO-CUTANIT, LTD. *Brit. Pat.* 679,413.

Recovery of Metals from Magnetic Alloy Scrap

Nickel-aluminium-cobalt-iron alloy scrap contaminated with oxides of aluminium and other metals is melted and heated, at a temperature above 3000°F. (1650°C.), with sufficient aluminium to convert the other oxides to aluminium oxide, and enough sodium oxide and silica to form a flux with all the alumina. The flux is separated, and the metal so reclaimed cast.

M. PESSES, assignor to ALTER COMPANY. *U.S. Pat.* 2,611,692.

Nickel-Chromium-Iron Alloy Moulds for Bending Glass

Cast moulds for use in bending glass are made from an alloy having a high density and high specific heat, so that the surface temperature of the mould lags behind that of the glass sufficiently to prevent the glass from fusing to the mould. The preferred alloy contains nickel 34-68, chromium 14-21, carbon less than 0·5, per cent., balance iron. Manganese, silicon, and nitrogen are limited to not more than 1 per cent. each. The preferred alloy contains nickel 35, chromium 15, carbon less than 0·5 per cent., iron balance.

LIBBEY-OWENS-FORD GLASS CO. *Brit. Pat.* 681,943.

High-Temperature Alloy having Good Working Properties

An alloy which can be hot-worked, has good casting properties, and is characterized by strength at temperatures of 600°-850°C., contains chromium 15-25, nickel 15-40, cobalt 5-30, molybdenum 0·5-7, tungsten 0·5-10, titanium and/or zirconium 1·0-3, niobium and/or tantalum 1-4, aluminium up to 1·5, carbon not more than 0·1, nitrogen not more than 0·100, per cent., balance iron. The following may also be present: manganese 2, silicon up to 1, vanadium up to 2, per cent. A preferred composition is given.

AVESTA JERNVERKS, A.B. (inventor: HELIN). *French Pat.* 1,007,996.

Alloys for Electrical Resistances and Furnace Parts

The following range of composition is given for alloys stated to be suitable for resistance elements and furnace parts:—nickel 35-90, chromium 10-30, niobium 0·2-5, iron trace —50, manganese 0-4, silicon 0-3, carbon 0-0·25, per cent. Preferred compositions are given. The alloys are claimed to be resistant to green rot.

BRITISH DRIVER-HARRIS CO., LTD. *Belgian Pat.* 509,242.

Hardening of Austenitic Steels by Working at Sub-Zero Temperatures

Mechanical properties and hardness of austenitic chromium-nickel steels are improved by cooling to a temperature within the range −50°F. to the boiling point of liquid nitrogen, and mechanically working within this range, this operation being followed by ageing at 500°-1000°F. (260°-540°C.). Steels suitable for such treatment are detailed.

CRANE COMPANY (inventors, N. A. ZIEGLER, W. L. MEINHART, J. R. GOLDSMITH). *Brit. Pat.* 683,557.

Copper Additions to Nickel-Chromium Steels to Stabilize the Austenite during Cold Working

Nickel-chromium stainless steels are made less susceptible to decomposition of austenite on cold working by the addition of copper in amounts just below the solubility limit. Examples quoted include:—(*a*) copper 1, nickel 18, chromium 8, per cent.; (*b*) copper 2, nickel 12, chromium 12, per cent.; (*c*) copper 4, nickel 12, chromium 18, per cent.; (*d*) copper 4, nickel 8, chromium 18, per cent.

STÉ. D'ÉLECTRO-CHIMIE, D'ÉLECTRO-MÉTALLURGIE ET DES ACIÉRIES ÉLECTRIQUES D'UGINE. *French Pat.* 1,009, 239.

Coated Austenitic Welding Electrodes

Core wires of austenitic electrodes consist of steel containing nickel 8-12, chromium 15-20, carbon 0·03-0·20, per cent., with the usual additions of molybdenum, copper, titanium, niobium: *alternatively* steels containing nickel 8-23, chromium 15-27, carbon 0·03-0·20, per cent., with or without niobium or titanium, *or* nickel-chromium-manganese steels. Coatings consist of (parts by weight) $CaCO_3$ 20-40, TiO_2 28-75, $Mg_3(OH)_3\ Si_4O_{10}$ 35-5. Quartz up to 15 parts and ferro-titanium, ferro-molybdenum, ferro-tantalum or ferro-niobium up to 15 parts may also be present.

GEBR. BÖHLER AND CO., A.G. *French Pat.* 1,008,300.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks.*

THE MOND NICKEL COMPANY LIMITED
SUNDERLAND HOUSE · CURZON STREET · LONDON, W.1

PRINTED IN ENGLAND *by* WIGHTMAN MOUNTAIN LTD.
WESTMINSTER, LONDON, S.W.1